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Climate Change in the Hudson River Estuary: Promoting Adaptation and Resilience through Stakeholder Engagement in Design and Visualization

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Climate change in the Hudson River Estuary: Promoting adaptation and resilience through stakeholder engagement in design and visualization.

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Dedication

I would like to dedicate this thesis to my mother for teaching me about the complex interrelations of the world and for always pushing me to improve my arguments.

Thank you to my family for the love of the outdoors I grew up with and our discussions and debates about politics over the years. My ability to think critically and make my points clearly has come from you, and so has my desire to make the world (at least a little bit) better.

To my amazing spouse Eleni, thank you for your support and your inspirational example of constant effort; and for being constructively critical when I need it. Without you I would have gained several more grey hairs over the past two years, and I definitely would not have had as much fun.

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Abstract

In response to the growing risk to communities from climate change impacts, Professor Cerra at the Cornell University School of Landscape Architecture developed the Climate Adaptive Design (CAD) program. CAD is being implemented as a partnership between the Hudson River Estuary Program (Estuary Program) and Cornell that utilizes participatory design and visualization to engage communities about planning for future climate impacts. The goal of CAD is to build climate resilience, galvanize community participation and education, and build links to external sources of support including local institutions of higher education. This thesis outlines background for the development of the program and reviews the literature with a focus on community resilience and adaptive, participatory planning and design. Based on this review, I developed a survey and metric for evaluating the resilience of communities participating in CAD or similar programs. Next, I describe case studies of communities that have already participated in the CAD program. Finally, I make policy recommendations based on these cases for further work by the Estuary Program through CAD or similar partnerships with higher educational institutions. By engaging municipalities in collaborative design, CAD aims to shift necessary conversations about climate adaptation to be a resilience-building and empowering process, and this thesis seeks to strengthen those efforts.

Executive Summary

Introduction

Our global climate is changing, and the Northeast United States is experiencing a greater increase in temperatures, sea levels, and rain event intensity than global averages (NOAA, 2017). In the past century the Northeast United States, including the Hudson River estuary in New York State, has seen days of 'very heavy precipitation'[1] increase by more than 70%, annual average temperature increase by over 2º, and sea level rise more than 12" (Walsh et al., 2014; NOAA, 2017).

To address these challenges, the Hudson River Estuary Program (Estuary Program), a part of the New York State Department of Environmental Conservation (DEC) has embarked on various efforts to improve the resilience of communities in the estuary to climate change impacts. One part of the Estuary Program's resilience-building effort is the Climate-Adaptive Design (CAD) studio, a partnership between the Hudson River Estuary Program (Estuary Program) and Cornell School of Landscape Architecture that utilizes participatory design and visualization to engage communities about planning for future climate impacts. The purpose of this document is to first expand methods to understand the resilience of CAD communities and then to use that understanding as a basis for discussions on the effectiveness of CAD thus far in inspiring resilience-building action, and make recommendations for continued work by the Estuary Program on this front.

Climate-Adaptive Design

CAD brings landscape architecture, urban planning, and engineering students from Cornell

[1] Defined by Walsh et al. (2014) "the heaviest 1% of all daily events." p.37

University to municipalities located in the Hudson River estuary watershed to develop designs that address projected risks from climate change while being responsive to community needs and site conditions. The assumption embedded in CAD is that collaborating with state agencies, local universities, and non-profit organizations can expand municipal capacity and bring new perspectives on how to address climate-related challenges to participating communities, while providing an educational benefit to students.

In the CAD studio, students under the supervision of Professor Cerra learn about the climate risks to a waterfront municipality and engage multiple community stakeholders, non-profit partners, and technical experts in an interdisciplinary process of design (Cerra, 2016). Designing for these waterfront communities requires gaining an understanding of climate adaptation along with a set of issues including ecology, economic development, and environmental justice (Cerra, 2016b; Zemaitis, 2016).

Through the course, students learn about the diverse needs, challenges, and opportunities in designing climate-resilient communities and gain vital real-world experience (Cerra, 2016). They present design options in progress to stakeholders to receive feedback which is then incorporated into their final designs, an iterative process of conversation and revision. Engaging in such an iterative, responsive design process and communicating expected performance are especially valuable aspects of CAD designs in responding to ever-shifting climate projections and community needs (Cerra, 2016; Folke, et al., 2002).

Partnering with academic institutions is a low-cost method to expand capacity with multiple potential co-benefits, providing improved educational experiences for students while offering innovative design and planning options to municipalities (Cerra, 2016). By reimagining climate change adaptation as a design challenge, CAD can be an inspirational opportunity to integrate community goals such as economic development with long-term planning for their built and natural environment.

Resilience and Adaptation

As the primary goals of the Climate-Adaptive Deign (CAD) program are to improve *resilience* and inspire *adaptation* to climate change by municipalities in the Hudson River estuary, definitions of these terms and an understanding of current models for achieving the goals of CAD is necessary in order to analyze the program. *Adaptation* is essentially any action that reduces the impact of climate change and *resilience* describes the ability of a system, natural or social, to recover, rebuild, grow, and even potentially become stronger as it is stressed or undergoes change (Folke et al., 2002; IPCC, 2014; Nelson, 2011).

As the discourse on resilience and adaptation has expanded, *community resilience* has become a focus of many policy-makers including the Estuary Program, who aspire to improve community resilience through their work (HREP, 2014; Stokols, Perez, & Hipp, 2013; Zemaitis, 2016). Community resilience is a hybrid of many spheres of resilience, including individual, physical, and governmental (Stokols et al., 2013). One strategy for making a community more resilient is to improve its ability to adapt as environmental and socio-economic circumstances change; using proactive adaptation strategies to achieve the long-term goal of thriving with change (Stokols et al., 2013; Nelson, 2011). The goals of the CAD program to inspire adaptive action and improve community resilience closely follow this trend.

A powerful method of building community resilience and encouraging adaptation described in the literature is *participatory planning* (Ling, Hanna, & Dale 2009*)*. Participatory planning involves stakeholders in decision-making and planning including ways to adapt and improve their community for the future (Adger, 2003; Ling et al., 2009). Showing stakeholders visual representations of plans or proposals can be used to improve engagement, better informing and educating those who may not be fluent in the language of planning (Sheppard et al., 2008).

This combination of participatory planning and visualization leads to *participatory design,* inviting community members to be a part of the imagining of their future built environment (Sheppard et al., 2008). By increasing information sharing and education, and providing aspirational ideas for future development, participatory design can spur action by community leaders and residents to work toward their jointly developed common goal(s) (Adger, 2003; Sheppard et al., 2008). CAD can begin to offer these benefits as it works with stakeholders, municipal leaders, the state, and other partners.

Methods

To describe strengths and weaknesses and offer insights on the Climate-Adaptive Design (CAD) partnership program, I developed a metric for community resilience and a method to track successful adaptation based on the literature. These metrics create an approach for evaluating participating communities' resilience and efforts at adaptation, and could potentially be utilized in the future to understand how those adaptation actions influence community resilience over time.

The resilience metric was designed to measure the baseline resilience of communities before participating in CAD, and potentially at a set time after CAD participation, to evaluate its impact. Social factors are emphasized to act in complement with existing measures that focus primarily on planning and physical factors already used by the Estuary Program such as the Climate Smart Resiliency Planning (CSRP) tool. The elements from the literature included in the metric are: leadership, good governance, stakeholder engagement, education, social capital, physical infrastructure, environmental hazard management, and long term planning. To score these elements, a questionnaire was developed asking respondents to rate their agreement with statements about each factor. The resulting questionnaire was piloted with stakeholders from the three communities that have participated in the CAD program so far. In addition, stakeholders identified by the CAD team as active participants in the process in their community were interviewed about the resilience factors, and the interviewees were invited to discuss additional topics they felt relevant to the CAD program.

To analyze the success of CAD in its second goal of inspiring adaptive action to build resilience, successful adaptation actions in literature were reviewed to develop a scorecard for tracking actions taken by communities during and after the CAD process that relate to the previously identified community resilience factors. Better tracking of adaptation measures will allow the Estuary Program to tailor its community outreach efforts to address actions that may need more support.

Discussion

The first three communities to participate in the Climate-Adaptive Design program were analyzed using these resilience and adaptation metrics in tandem, along with interview responses, discussion with Estuary Program staff, and review of student designs. To date, the Village of Catskill participated in the Fall semester of 2015, the City of Hudson in the Spring of 2016, and Kingston in Fall 2016 have participated in the CAD program (Zemaitis, 2016).

While there are many differences among these municipalities, each faces significant climate change risks. These risks include more frequent flooding from sea-level rise, intense precipitation, stormwater runoff, and storm-surge, along with heat stress and short-term drought (NYSERDA 2014; WRI, 2016). In addition, each of these communities is engaged in ongoing work with the Estuary Program and expressed interest in participating in CAD.

Based on survey response, among the three communities 'Education,' 'Infrastructure,' and 'Long term planning' are seen as the least resilient in the three communities. Though perceptions of stakeholder engagement by those surveyed was relatively high, longer-form survey responses and interviews indicate that residents and business owners in or adjacent to the project sites and especially minority populations or those not typically involved in community processes, have only been engaged in limited ways (C1, 2016; H1, 2016; K1 2016; Weiss, 2017a, b, c). This lack of outreach seems to be a product of the challenging task of engaging populations who may not be well-integrated into community discussions combined with concern that having too many stakeholder voices could over-complicate the CAD process (Cerra 2016c; K1, 2016; C1, 2016; Zemaitis, 2016).

Survey and interview responses indicate that while stakeholders and other participants may have been aware of climate change before participating in CAD, the program expanded understanding of climate change impacts, particularly at a local and regional scale (C1, 2016; H1, 2016). Further, participants gained knowledge of adaptation options that can be implemented in their community (C1, 2016; H1, 2016). Municipal leaders have been educated about adaptation options, both near and long-term available to them, and provided with graphical outreach and educational tools in the form of final design boards (C1, 2016; Zemaitis, 2016). However, as the metric indicates that education about climate change continues to be seen as a weakness, these newly educated leaders and CAD participants should be encouraged to share their learning with their communities.

In evaluating adaptation actions, the majority of actions undertaken so far in the three communities have centered on building social adaptive capacity or social capital, with less emphasis on the environment. It is a positive sign that local participants in CAD have been motivated to take at least first steps toward adaptive action, including planning green infrastructure installation in Catskill and restarting the Local Waterfront Revitalization Planning process in Hudson.

Policy Recommendations

As the Climate-Adaptive Design (CAD) program continues to engage with communities in the Hudson River estuary watershed, the following three recommendations to improve the program should be considered.

Resilience survey and metric. To address the social component of resilience, the survey and metric developed for this research are designed to be brief, flexible, and relevant to the concerns of municipalities in the Hudson River estuary watershed. This metric can be used with multiple stakeholder groups in multiple communities throughout the estuary watershed. By using these tools, the Estuary Program can gain insight into social factors and therefore develop a more holistic understanding of resilience within the estuary and how it evolves over time. Further, this tool can identify knowledge gaps between physical projects and planning work and perceptions of stakeholders.

Expand outreach and improve stakeholder engagement. A majority of participants surveyed and interviewed from all three communities felt that a greater number and diversity of stakeholders would improve students' learning during CAD as well as the usefulness of recommendations to communities (Weiss, 2017; Richards, 2017; H1, 2016). Giving voice to multiple viewpoints and avoiding prioritizing one set of stakeholders over another will result in more meaningful participation and therefore more meaningful student designs (Luyet, 2012; Richards, 2017; Zemaitis, 2016). A broad range of communication and outreach techniques to provide clear information and encourage attendance at CAD events should be used (Burch et al., 2010; Luyet et al., 2012). The Estuary Program should further provide guidance to municipalities on what to do with student designs once the semester is over and as recommended by Sheppard (2015), encourage the use of these visual products to develop conversations around the futures they envision.

Promote implementation of CAD recommendations. Continuing the conversation inspired by CAD should also include discussion of planning and implementation options within the municipality and support for this by Estuary Program. It is particularly important to educate municipal staff and others working within and in conjunction with the municipality about CAD recommendations and discuss their implications. The Hudson River Estuary Program and the Department of Environmental Conservation (DEC) can also fund implementation of CAD designs, particularly in their capacity as grantors. Providing municipalities that often have limited staff and financial capacity with technical assistance and funding for implementation where possible will improve adoption of CAD recommendations.

Conclusions

Climate change is rapidly shifting the natural environment, and communities are facing great challenges in adapting their built environment to these shifts. Using adaptation to build the resilience of communities is a strategy advocated throughout the literature, as is the use of visualization (Sheppard, 2015). Experts further emphasize the importance of engaging stakeholders in participatory design and visualization to build community adaptive capacity and resilience (Burch et al., 2010; Luyet et al., 2012). Provided a greater number and diversity of stakeholders can be engaged, the participatory planning and design process of CAD can help communities come together to meet these challenges. The course can help both groups expand their ability to envision ways to adapt and even thrive in a future with a changing climate (Cerra, 2016b).

Integrating CAD into the Estuary Program's work is allowing the organization to grow its traditional education and conservation roles and expand stakeholder outreach. Incorporating design and visualization of adaptation and resilience, CAD has the potential to increase engagement with businesses and residents who may not have previously been well-incorporated in public conversations (Zemaitis, 2016; Marcell, 2017). CAD can make necessary climate adaptation part of a positive, growth-oriented process that increases the resilience of a community physically through building projects, and socially through education and cooperation.

Chapter 1. Introduction

Our global climate is changing, and the Northeast United States is experiencing a greater increase in temperatures, sea levels, and rain event intensity than global averages (NOAA, 2017). In the past century the Northeast United States, including the Hudson River estuary in New York State, has seen days of 'very heavy precipitation'[2] increase by more than 70%, annual average temperature increase by over 2º, and sea level rise more than 12" (Walsh et al., 2014; NOAA, 2017). These changes in the global climate system can come together to fuel hurricanes and post-tropical systems such as Sandy, Irene, and Lee, with disastrous impacts in New York to waterfronts from New York City northward into the Hudson Valley (Stanne, 2012; NYSERDA, 2014).

Though climate change was seen as a growing concern by New York State and local environmental non-profits before the storms, they helped to galvanize groups to take action (Marcell, 2016; Zemaitis, 2016). New York first undertook research to understand potential climate change impacts, downscaling global climate models from the IPCC Fifth Assessment Report (AR5) to arrive at projections for sea-level rise, temperature, precipitation, and frequency of extreme events. As a baseline for discussion of climate change in this thesis, projections published by the New York State Energy Research and Development Authority (NYSERDA, 2014) in its document "Climate Change in New York State" along with updated sea-level rise projections published by the state of New York in January of 2017 as part of ongoing rule making for the Community Risk and Resiliency Act (CRRA) are used. See Appendix A for a discussion of global climate projections. In these documents, the Hudson

[2] Defined by Walsh et al. (2014) "the heaviest 1% of all daily events." p.37

River estuary is referred to as both the ‘Mid-Hudson Region’ and ‘Region 5’ (New York, 2017; NYSERDA 2014). Ranges are provided for potential future conditions in 30 year intervals. Table 1 below shows the middle range, between the 25th and 75th percentile of likelihood of occurrence, of average temperature increase, sea level rise, days of intense precipitation (over 1” of rainfall), and days of excessive heat (over 90º F) projections for the Hudson River estuary until 2080 (New York, 2017; NYSERDA 2014).

Table 1. Climate change projections for the Hudson River Estuary

Year	Temperature (ºF)	Sea level rise (inches)	Intense precip. (days)	Excess heat (days)
2020	+ 2.3 - 3.2º	3 - 7”	10 - 11	17 - 22
2050	+ 4.5 - 6.2º	9 - 19”	11 - 12	27 - 41
2080	+ 5.6 - 9.7º	14 - 36”	11 - 13	35 - 70

Source: NYSERDA, 2014; New York, 2017

Due to the potentially catastrophic impacts of these projections to human and natural systems throughout the state, New York State has decided to become a leading actor in responding to climate change (Marcell, 2016). These actions include both *mitigation* by reducing greenhouse gasses and *adaptation* to the changing environment. Mitigation policy actions taken by New York include adopting more stringent emissions standards for vehicles, a regional carbon dioxide cap-and-trade scheme called REGGI[3] , as well as renewable energy research and installation through NYSERDA (Chasek et al., 2010; NYSERDA 2014). Legislatively, the Community Risk and Resiliency Act (CRRA) passed in 2014 requiring the consideration of climate risks for all permitting, planning, and environmental impact studies (Marcell, 2016).[4]

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[3] The Regional Greenhouse Gas Initiative (RGGI). For information on RGGI and other cap and trade policies, see Betsill, M. and Hoffmann, M. J. (2011): “The Contours of ‘Cap and Trade’: The evolution of emissions trading systems for greenhouse gases. *Review of Policy Research.* Volume 28. 83–106.

[4] See Appendix A for further information on climate change policy on a global and federal scale.

In line with this consideration, New York has elected to require more stringent flood plain management standards than those required by the Federal Emergency Management Agency (FEMA), specifically requiring residences to be built or raised well above projected future flood elevations that now include sea-level rise (New York, 2017). Another program, a hybrid of mitigation and adaptation policies, has been established by New York called Climate Smart Communities (CSC). CSC is a multi-faceted effort to encourage municipalities throughout the state to undertake a broad range of actions by supporting planning and implementation with technical assistance and funding (NYSDEC, 2009).

Many communities threatened by potentially negative climate change impacts are within the tidal Hudson River watershed, where the Hudson River Estuary Program (Estuary Program), a part of NYS DEC, is promoting multiple initiatives to help communities adapt and become more resilient to climate change (HREP, 2014). One part of HREP's resilience-building effort is the Climate-Adaptive Design (CAD) studio. CAD brings landscape architecture and engineering students from Cornell University into municipalities located in the Hudson River watershed to develop designs that are responsive to site conditions and address projected risks from climate change. CAD's goals are to inspire action that addresses significant climate-related challenges while educating the next generation of design and planning professionals.

The assumption embedded in CAD is that collaborating with state agencies, local universities, and non-profit organizations can expand municipal capacity and bring new perspectives on how to address significant climate-related challenges to participating communities, while providing an educational benefit to students. This thesis provides an overview of the CAD program and reviews its effectiveness thus far. The purpose of this document is to first expand methods to understand the resilience of CAD communities and then to use that understanding as a basis for discussions on the effectiveness of CAD thus far in inspiring resilience-building action.

The thesis uses a set of methods, including primary and secondary research. First, I provide an overview of the Climate Adaptive Design (CAD) program including its strategy and goals. This overview is followed by a discussion of the literature on the two interrelated policy goals of the program; building resilience and inspiring adaptation. Next, I review methods in the literature that use social tactics including participatory planning and design to increase resilience and build adaptive capacity and action. Case studies of three participating communities, including survey and interviews, are reviewed through the dual lenses of resilience and adaptation. Using examples from the cases and literature I recommend next steps for the CAD program and strategies to inform continued work with municipalities that have already been engaged. I conclude by reviewing the importance of partnering with higher education institutions to offer programs like CAD to create resilience and successful planning efforts.

Chapter 2. The Climate-Adaptive Design Program

As a partnership between the state, higher education, and local municipalities, CAD is an innovative way to expand state and municipal capacity and provide practice-based learning opportunities for students (Cerra, 2016b; Reardon, 2006). This chapter first describes the origins of the Climate-Adaptive Design (CAD) program. Next, the strategies of the program and the basic course process are explained. Finally, the goals and potential advantages of this type of partnership with higher education institutions are identified.

Municipalities participating in the Climate-Adaptive Design (CAD) program face multiple climate change-related challenges including inland flooding, sea level rise, increasing average temperatures, and short-term drought (NYSERDA, 2014). As with many areas throughout the country, the participating communities are not only physically vulnerable because of their geographic location, but also socially and economically vulnerable because of their limited personnel and resources (HREP, 2015).

Origin

The CAD program developed out of the climate resilience work being led by communities and the Hudson River Estuary Program. Four community “Flooding Task Forces” were created in Catskill, Hudson, Kingston, and Piermont along the Hudson River of New York State (HREP, 2015). The Task Forces were convened by the Estuary Program in response to the historically damaging storms of Irene, Lee, and Sandy in (2010-2012) to examine current and future climate risks, strategies being employed around the world, and make recommendations on how each community could reduce its risks and become more resilient

(HREP, 2015). Many of the recommendations focused on adapting to climate risks, including raising buildings, increasing stormwater storage capacity, and relocating out of flood zones (Catskill, 2014; Kingston, 2014). Throughout these processes, there was repeated desire expressed by Task Force members for assistance in envisioning how these adaptations could take shape and be feasible in a small community, not only in terms of policy but also physical design and implementation (Zemaitis, 2016).

In response, the Hudson River Estuary Program (HREP) developed a partnership called the Climate-Adaptive Design (CAD) program with Professor Cerra at the Cornell University School of Landscape Architecture. Professor Cerra was developing a framework for landscape climate adaptation, a natural link to the goals of the Task Forces (Cerra, 2016b; Zemaitis, 2017). CAD brings teams of landscape architecture students through a studio course to communities to help them understand their options to adapt to climate risks (Zemaitis, 2016).

Climate-Adaptive Design (CAD) study sites are selected through discussion between Hudson River Estuary Program staff, Cornell Cooperative Extension (CCE) staff, Professor Cerra from the Cornell Department of Landscape Architecture, and municipal leaders. When a community is selected to participate in CAD, a liaison (generally a public employee or committee member) is designated and becomes the primary point of contact between the CAD program and the municipality. It is with their guidance and conversations with Professor Cerra that a specific site within the municipality is selected for study.

Strategies

In this studio, students under the supervision of Professor Cerra learn about the climate risks to a waterfront municipality and engage multiple community stakeholders as well as non-profit partners and technical experts in an interdisciplinary process of design (Cerra, 2016). During the course, students develop potential strategies that enhance waterfront resilience to climate change and respond to the needs of the community (Cerra, 2016b). By reimagining climate change adaptation as a design challenge, CAD can be an inspirational opportunity to integrate community goals such as economic development with long-term planning for their built and natural environment.

Designing for these waterfront communities requires gaining an understanding of climate adaptation along with a set of issues including ecology, economic development, and environmental justice. Therefore, students learn about the diverse needs, challenges, and opportunities in designing climate-resilient communities and gain vital real-world experience. In turn, the CAD program attempts to add discussion about climate adaptation into conversations within communities.

Professor Cerra and his students have the ability to examine options and present planning concepts in an accessible manner to municipalities and stakeholders who often have limited time or training to engage in climate adaptation on their own (Cerra, 2016b; Reardon, 2006). As student projects, proposals can take on aspirational goals and be less hampered by political or budgetary constraints than traditional consultant work (Zemaitis, 2017). Further, the University's position as a respected research institution can help open doors with stakeholders that may ordinarily be resistant to discussions of climate change or development options (Reardon, 2006; Zemaitis, 2017).

The program works to inform community members about their current climate risks through mapping and visualization and invites them to participate in imagining ways to adapt to those risks (Zemaitis, 2016). Understanding risks and discussing adaptation options helps to build the resilience of communities (Adger, 2003; Ling, Hanna, & Dale, 2009). Further, CAD reframes adaptation as a component of positive forward-thinking development rather than reactionary rebuilding after a climate-related shock (Cerra, 2016c; Zemaitis, 2016). Stakeholder participation is vital to this program, since students develop more informed and responsive designs based on their input (Zemaitis, 2017). Luyet et al. (2012) discuss that participation in such programs can increase ‘buy-in’ and implementation of recommendations.

Increasing both financial and personnel capacity within and across municipalities to deal with major issues including climate change is essential to improving resilience, especially in smaller communities with limited budget and staff (HREP, 2015; Zemaitis, 2016). Partnering with academic institutions is a low-cost method to expand capacity with multiple co-benefits, providing improved educational experiences for students while offering innovative design and planning options to municipalities (Cerra, 2016).

The Course

As shown in Figure 1, Professor Cerra’s studio spans one semester and brings students from site characterization through analysis and schematic design. Professor Cerra (2016b) first introduces students to the project in the studio, referencing existing plans and maps to give a broad overview of the site. This is followed by a site visit early in the semester where students meet with stakeholders to learn their needs and goals for the area, and document the site through photographs, sketches, and notes (Cerra, 2016b). Throughout this introductory phase, students begin to identify design challenges both climate-related and otherwise (Cerra, 2016b). Students then return to the studio to do further, in-depth research into existing plans and challenges for the site, and examine precedents of how other municipalities throughout the U.S. and elsewhere have managed such challenges (Cerra, 2016b).

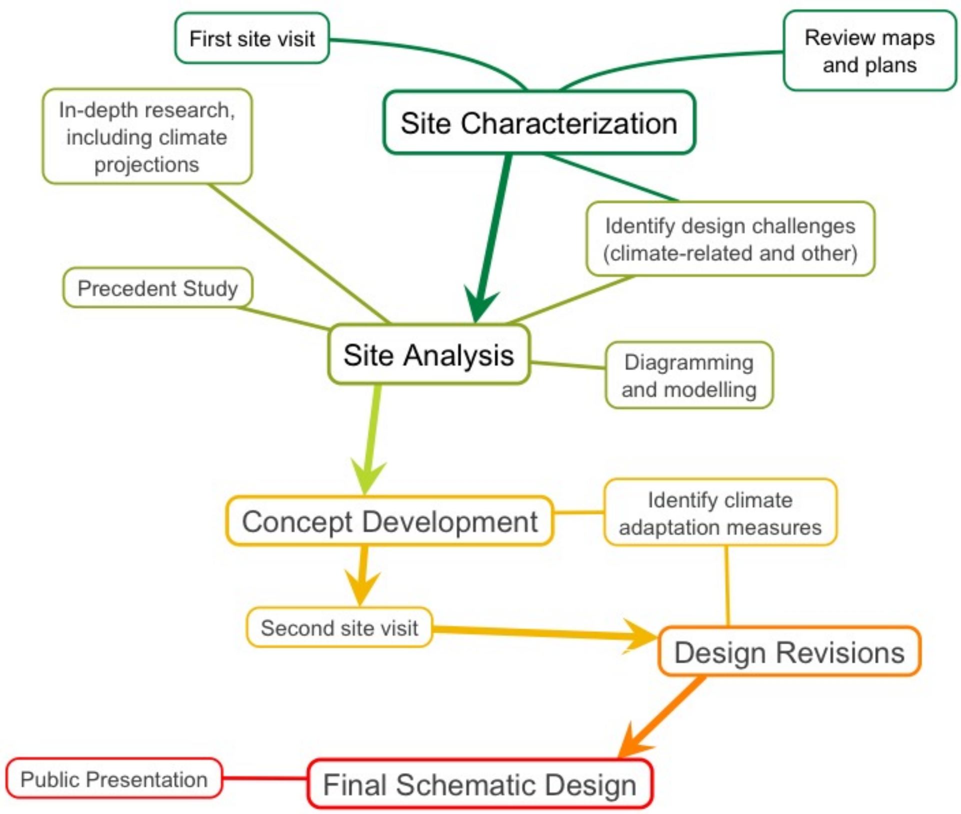

Figure 1, Studio course process
Source: Cerra, 2016b

Professor Cerra's (2016b) approach utilizes a rubric where projected climate impacts are paired with associated adaptive design responses and metrics to assess their potential performance under projected climate scenarios. The expected performance of each design can be quantified and individual plans compared using measures such as amount of floodable land, amount of stormwater storage provided, and amount of shade created among others (Cerra, 2016b). Approaches such as this that engage in an iterative, responsive design process and communicate expected performance are especially valuable in responding to ever-shifting climate projections and community needs (Cerra, 2016; Folke, et al., 2002).

For approximately six weeks after their first visit, students engage in extensive research and conduct S*ite Analysis* (Cerra, 2016b). This research has included speaking with local transportation planners, obtaining hydrological modeling through a partnership with Professor Todd Walter and students in his Cornell School of Biological and Environmental Engineering Watershed Engineering course, as well as expert lectures on making sites accessible to persons with disabilities, shoreline stabilization techniques, habitat and ecological considerations, and more. Beginning the C*oncept Development* phase of the course, the students' first assignments as design teams are to develop initial design concepts that are quickly brought back to the community in a "speed-dating" style workshop; student groups present their designs at a table and stakeholders rotate through, providing feedback. Students take this input back to the studio for further revision and iterations informed by continued research and review by Professor Cerra and other experts (Cerra, 2016b).

At mid-term, student groups display their progress to a panel of expert critics, including Landscape Architecture faculty, practicing Landscape Architects, and staff from the Estuary Program and Cornell Cooperative Extension. Based on these critiques and guidance from Professor Cerra, students move into the *design revisions* phase of the course where designs are again revised and developed into posters ready for display at a final open-house style event in the community (Cerra, 2016b). Stakeholders are invited, a brief introductory talk is given on how the designs developed, and all are invited to walk around and view the designs, meet with students, and learn from each other. Once the open house is complete, paper and digital copies of the students' work is given to the municipality to utilize for exhibits, discussion, and outreach.

Through this studio course, Professor Cerra (2016b) is working to educate the next generation of landscape architects about climate adaptation as well as raise awareness among professional designers and partners. Adaptation in this context includes an understanding of urban ecosystem services, climate change risks, and even mitigation via mechanisms such as energy efficiency, multi-modal transportation, and urban heat island reduction (Cerra, 2016b).The Estuary Program sees CAD as a method to, through the inspirational ideas of students, encourage municipalities to build resilience to projected climate change hazards through education and adaptation.

Increasing both financial and personnel capacity within and across municipalities to deal with major issues including climate change is essential to improving resilience, especially in smaller communities with limited budget and staff (HREP, 2015; Zemaitis, 2016). Partnering with academic institutions is a low-cost method to expand capacity with multiple co-benefits, providing improved educational experiences for students while offering innovative design and planning options to municipalities (Cerra, 2016). The Climate-Adaptive Design (CAD) program is such a partnership, expanding capacity not only of municipalities but also of the Estuary Program through its partnership with Cornell.

Chapter 3. Resilience and Adaptation

As the primary goals of the Climate-Adaptive Design (CAD) program are to improve resilience and inspire adaptation to climate change by municipalities in the Hudson River estuary, definitions of these terms and an understanding of current models for achieving the goals of CAD is necessary in order to analyze the program. This chapter first defines the terms 'adaptation' and 'resilience' as they relate to climate change. Resilience in particular is examined in detail, focusing on social aspects and community resilience. Second, I review factors in the literature contributing to resilience, with a focus on community resilience. Third, I review discussion in the literature building that resilience using adaptation measures.

Definitions

Resilience

Resilience describes the ability of a system to recover, rebuild, grow, and even potentially become stronger as it is stressed or undergoes change (Folke et al., 2002; Nelson, 2011). It has become a popular concept in recent years in disciplines from psychology to ecology, emergency management, and even within the military. While the precise definition of 'resilience' varies across fields, it originates from an ecological concept that systems tend toward equilibrium or balance, and their resilience is their ability to return to that state of equilibrium (Eakin & Luers, 2006; Gunderson, 2000). If the system does not return to its state of equilibrium after a shock, it is considered to have crossed a 'threshold' into a new state (Eakin & Luers, 2006). See Appendix A for more discussion and a diagram of resilience and threshold conditions.

Resilience applies not only to natural systems but also to the built environment, socio-economic, and political systems (Ahern, 2011; Folke et al., 2002; Kerner & Thomas, 2014). This type of resilience is referred to in the literature as social resilience (Adger, 2003; Folke et al., 2002). Starting at the individual level, social resilience centers on the ability of people to cope with and continue to thrive under stress (Kerner & Thomas, 2014). The collective ability of people to handle that stress contributes to a resilient community (Kerner & Thomas, 2014; Nelson, 2011).

Community Resilience

As the discourse on resilience and adaptation has expanded, *community resilience* has become a focus of many policy-makers (Stokols, Perez, & Hipp, 2013). This includes the Hudson River Estuary Program (Estuary Program) and the Climate-Adaptive Design (CAD) program within it, who aspire to improve community resilience through their work (HREP, 2014). Community resilience is a hybrid of physical and social resilience, including individual, environmental, physical, and governmental resilience (Stokols et al., 2013).

One key to making a community resilient is improving its ability to adapt as environmental and socio-economic circumstances change; using proactive adaptation strategies to achieve the long-term goal of thriving with change (Stokols et al., 2013; Nelson, 2011). The quantity and quality of social capital, leadership, and stakeholder participation directly impact community resilience (Adger, 2003; Harrison et al., 2016). The goals of the CAD program to engage communities and inspire adaptive action as a method to improve community resilience closely follow this trend.

Adaptation

The IPCC (2014) defines adaptation to climate change as:

> "The adjustment to practices, processes and systems in order to ameliorate negative effects and take advantage of opportunities associated with climate change.’’

Essentially, adaptation is an action that reduces the impact of climate change. The process or concept of adaptation is a much lauded goal within the literature, but its definition is often vague and varies between authors and disciplines from economics to geography (Doria et al., 2009). The literature includes many different views on what adaptive actions should be and who should take them, making it difficult to create a concise description of the concept (Doria et al., 2009).

Despite this conflict, there is consensus that in order to effectively adapt, scientists, policy makers, and stakeholders, must work in concert (Nelson, 2011; Doria et al., 2009). Scientists inform plans by modeling climate systems to project future temperature and precipitation patterns while policy makers, planners, designers, and stakeholders shift how we build and live so that we cannot only be safe but thrive under current and future conditions (Adger, 2003; Nelson, 2011). A commonality within the multiple sources reviewed by Biagini et al. (2014) is the division of adaptation into three general categories; ’recognition’ or education, building adaptive capacity through policy, and physically constructing adaptive projects.

Adaptation is emphasized as a necessary action at the community scale by Nelson (2011), who points out that since we are already set on a trajectory for significant climate change impacts, we must therefore adapt to them. However, he warns that local adaptation can have larger ramifications as adaptive efforts to maintain the current state by multiple communities can aggregate to cause downstream harm or even make us inflexible. It is also important to consider whether adaptation should be undertaken to increase the resilience of the existing system and perpetuate it, or instead be part of a process of changing the system to a new presumably more resilient state (Eriksen, 2011; Nelson, 2011). These warnings provide a useful counterpoint to the generally positive impression of adaptation but there is general agreement that when well planned, adaptation to climate hazards improves the resilience of a community and society at large (Adger, 2003; Doria et al., 2009).

Measuring Resilience

In order to determine if CAD improves community resilience, we first need an approach to measure it. There is a long history of evaluating the resilience of infrastructure and the physical environment through programs such as the Department of Homeland Security (DHS)'s Critical Infrastructure Resilience Institute, and of using metrics such as the Climate Smart Resiliency Planning (CSRP) tool in New York state. While the CSRP tool tracks planning documents and physical infrastructure projects, measuring the social aspects of community resilience can be more difficult due to its reliance on dynamic factors such as social capital and education (Harris et al., 2016; Marcell, 2016; NYSDEC, 2009). Understanding the social aspects of a community's resilience is essential since groups of people are in the end, responsible for taking adaptive or mitigative actions (Adger, 2003; Kerner & Thomas, 2014).

By reviewing indicators and scorecards in the literature, this work aims to find commonalities among them with an emphasis on measuring social aspects of community resilience. Improving understanding of social factors will enable the Estuary Program and partners to develop better strategies to address and improve this essential element of community resilience in conjunction with their ongoing work on physical factors. Six strategies for measuring resilience were selected based on their inclusion of climate change risks, recent development to ensure relevance, and use by nonprofits and governmental agencies.

A starting point for many resilience measures is disaster (FEMA, 2016; UNISDR, 2015). In these documents, the need for advance planning and education about risk, response, and recovery from disasters throughout government processes is emphasized (Atreya & Kunreuther, 2016; UNISDR, 2015). An example is the points given to communities in the US participating in the Community Rating System (CRS) of the National Flood Insurance Program (NFIP)[5] for developing flood plain zoning regulations and educating residents in those areas (Atreya & Kunreuther, 2016). Since CAD directly addresses these issues, the program could assist communities in earning points in the CRS.

Throughout the literature, different methods are used to measure and identify factors important to community resilience. Using capital types, indicators, and ‘essentials’ among others, authors attempt to develop streamlined methods for evaluating the resilience of communities, tallied on a spreadsheet or checklist (Arup, 2015; Atreya & Kunreuther, 2016; DHS, 2016; FEMA, 2016; UNISDR, 2015). A common feature of the City Resilience Index (City RI), Community Resilience Indicators (DHS CRI), Community Resilience Index (Comm RI), the Community Rating System (CRS), is the use of documentation (e.g.

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[5] See Appendix A for a description of the NFIP and CRS.

adaptation plans) and evaluators to assess resilience factors (Arup, 2015; Atreya & Kunreuther, 2016; DHS, 2016; FEMA, 2016; UNISDR, 2015). Though the DHS CRI and City RI include surveying as a method to evaluate engagement, they do not use surveys as an overall assessment tool (DHS, 2016; Arup 2015). Using evaluators necessarily incorporates their perspective, a potential stumbling block for better understanding stakeholder priorities for resilience and how well-informed community members are about resilience issues. Both factors, community needs and education, are key components to resilience itself (Atreya & Kunreuther, 2016; Kerner & Thomas, 2014). Kerner and Thomas (2014) propose in their Resilience Attributes (RA) that managers and municipal leaders evaluate their own communities for factors and processes that impact resilience in categories of 'stability,' 'adaptive capacity,' and 'readiness.'

The six measures reviewed were analyzed using a keyword and concept search to identify common factors identified as contributing to resilience with an emphasis on social factors not well covered by the NYS DEC Climate Smart Resilience Planning (CSRP) tool. Marked cells in Table 3 indicate discussion of that resilience factor in the document.

Table 3, Common factors contributing to resilience

Factor	UNISDR	DHS CRI	CRS	City RI	Comm RI	RA
Leadership	●	●		●		●
Good governance	●	●	●	●		
Stakeholder Engagement	●	●	●	●	●	●
Education	●	●	●	●	●	●
Social connections/ capital	●	●		●	●	●
Physical infrastructure	●	●	●	●	●	
Address environmental hazards	●	●		●	●	●
Long term planning	●	●	●	●	●	●

Municipal leadership is important not only in identifying risks but also in leading by example by choosing to address the threat climate change poses (UNISR, 2015; Arup, 2015). The ability to honestly identify and communicate vulnerabilities is essential to creating transparent, responsive, good governance (Kerner & Thomas, 2014). It is important to engage all stakeholders and especially historically underrepresented people in this effort, as they are often those that are most negatively impacted when the system of the community proves to not be resilient (Arup, 2015). Educating stakeholders about how their community's systems function and interact empowers them to improve the resilience of their community (Kerner & Thomas, 2014). This process of engagement and education leads is linked to social capital, emphasized by several measures as a building block of cooperation for long-term resilience building efforts (Atreya & Kunreuther, 2016; DHS, 2016; FEMA, 2016; UNISDR, 2015).

While I have focused on social factors to act in complement to the CSRP tool, there are significant impacts to community resilience from physical infrastructure (FEMA 2016; UNISDR, 2015). Vulnerability to slowly building risks such as sea level rise and ecosystem degradation are essential to consider in addition to impacts of a specific shock or disaster such as flood or earthquake (Arup, 2015; DHS, 2106; Kerner & Thomas, 2014). Management of environmental hazards from natural to man-made and ranging from eroded stream banks to brownfields increases the health of the community as a system and correspondingly, its resilience (Arup, 2015; Atreya & Kunreuther, 2016; DHS, 2016).

Thoughtful, achievable, and clearly communicated plans are essential for building the resilience of communities (Arup, 2015; Atreya & Kunreuther, 2016; DHS, 2106; FEMA, 2016; Kerner & Thomas, 2014; UNISDR, 2015). The framework of questions developed by Kerner and Thomas (2014) uses clear language to describe concepts and create questions to enable stakeholders to evaluate their own community. Questioning the stability of the current state and the ability of a community to prepare for and deal with changing circumstances brings concepts of external support and adaptation into consideration, elements that CAD addresses.

Building Community Resilience

Inspiring adaptive action as a method to build community resilience is the second key policy goal of CAD. As shown in the examples described in Table 2, an *adaptation* is an action responding to specific hazards. *Community resilience* is built as adaptation actions are integrated into policy, planning, and other ongoing processes (Cerra, 2016; HREP, 2015; Nelson, 2011).

Table 2. Adaptation and Resilience

Hazard	Adaptation	Community Resilience
Sea-level rise	• Build berms and sea walls at areas of critical infrastructure. • Remove buildings and infrastructure to establish wave-attenuating and water-storing marsh where possible. • Develop emergency plans for flood events. • Convene community groups.	• Incorporate future projected sea levels in long-term planning. • Projects that are floodable or flood-proofed are built and their effectiveness evaluated. They are updated accordingly. • Community organizations assist each other with projects or during emergencies.
Increased heat wave frequency	• Plant trees that will thrive in the projected climate, especially in urban areas, to provide shade and cooling. • Install green roofs to keep buildings cooler. • Establish cooling centers.	• Trees thriving, increasing shade and cooling. • Roofing materials are reflective or green and keep building and surround areas cool • Cooling centers are used on days of excessive heat.

Sources: Cerra, 2016; Adger, 2003; Biagini et al., 2014

Counter to the daunting scale of global greenhouse gas emissions mitigation, adaptation can be implemented through discrete construction projects and planning processes, making it an attractive and empowering option for communities who may be fearful of or discouraged by climate impacts they feel they are unable to mitigate (Bassett & Fogelman, 2013; Zemaitis, 2016). An example is to rebuild or develop individual properties to be ‘floodable’ using materials that are undamaged by water and sloping surfaces that quickly drain water away after inundation (Ahern, 2011; Nelson, 2011). The concept of thresholds and multiple potential equilibria from ecology as discussed in Appendix A is a valuable frame in this context, as not all systems impacted by climate and other changes will be able to or should maintain their current structure. Adaptation may not necessarily mean increasing the resilience of the status quo but instead transitioning a system in response to or anticipation of climate shifts to a more resilient one (Eriksen et al., 2011).

A community’s ability to achieve their adaptive goals, especially in the face of significant challenges such as limited staff capacity, budget, or great hazards, is in large part reliant on factors including leadership, community engagement, and other aspects of community resilience (Adger, 2003; Harris et al., 2016; Kerner & Thomas, 2014). Adapting at this scale is not only vital for municipalities and their citizens to weather challenges from climate change but also a good laboratory to test strategies on a small scale before proposing them at national or global levels (Stokols et al., 2013).

Evaluating Adaptation

To inform a clear evaluation of CAD’s impact on adaptation, an understanding of successful adaptive actions, specifically to address the resilience factors identified as relevant for Hudson River estuary communities, is needed. A review of climate change adaptation literature was conducted and five sources were selected based on having a clear definition of successful adaptation, discussion of specific adaptation actions and impacts, and citation by experts in the field. Biagini et al. (2014)'s identification of ten categories of adaptive actions they found in the literature and Global Environment Facility projects,

> "Human or Social Resources or Capital (Capacity Building); Governance and Institutional Management and Planning (Man- agement and Planning); Changes in or Expansion of Practice or Behavior (Practice or Behavior); Governance and Institutional Policy Reform (Policy); Information and Communications Tech- nology (Information); Climate-Resilient Physical Infrastructure Adaptations (Physical Infrastructure); Early Warning Systems or Global Climate Observing Systems (Warning or Observing Systems); Climate-Resilient Biophysical or ''Green'' Infrastructure (Green Infrastructure); Adaptation Related Financial Strategies (Financing); Expansion or Introduction of Climate Adaptation- Related Technology (Technology)" (p.102)

highlights the broad array of potential actions, and the need for understanding context, potential impacts, and actors for each. Each document was reviewed for insight into how adaptive actions can addresses the relevant resilience factors.

Education of decision makers as well as stakeholders is an essential first step in adaptation (Biagini et al., 2014). They not only need to recognize the threat they are adapting to but also understand options for adaptive action (Biagini et al., 2014). Engaging stakeholders in participatory processes can extend beyond conventional public meetings to include data collection by citizen-scientists and participatory design, all of which further educate those engaged (Biagini et al., 2014; Eriksen, et al., 2011; Sheppard, 2015). In general, consultation with stakeholders results in more effective projects and a more informed process (Biagini et al., 2014; Luyet et al., 2012).

As adapting infrastructure to be resilient to climate impacts is an area where government action is necessary, how flexible those adaptations are and when they are undertaken are key (Eriksen, et al., 2011). For example advance planning and construction of elevated roadways is seen as preferred versus reactive action post-disaster (Adger, 2005; Biagini et al., 2014). At the municipal level, policy signals such as floodplain overlay districts in zoning can influence the private sector in the types and locations of projects they undertake (Adger, 2005; Nelson, 2011). Issues of equity and power are particularly important to consider in planning such interventions and broad stakeholder participation, particularly by underserved groups, is presented as a potential method to ensure these concepts are addressed (Biagini et al., 2014; Doria et al., 2009).

Long term planning, especially for actions that are costly or must be implemented over longer timescales, should be an ongoing effort and integrating climate adaptation into those existing processes is recommended (Biagini et al., 2014). Conserving and restoring habitat or ecosystem complexity is an example of this type of process. When planned as adaptive actions, such efforts can make that specific ecosystem more resilient and also offer significant ecosystem services to local populations, increasing the community's resilience as a whole (Adger, 2005; Biagini et al., 2014).

Throughout these adaptation efforts, local context, multiple sources of stressors, unforeseen consequences, and thresholds beyond which adaption is no longer desirable over a system shift, all require consideration (Eriksen et al., 2011; Nelson, 2011). Doria et al. (2009) further emphasize this point, finding agreement among experts that adaptation should "reduce the risks associated with climate change… without compromising economic, social, and environmental sustainability" (p. 815).

Adaptation actions with the goal of improving the previously identified relevant elements of resilience, leadership, good governance, stakeholder engagement, education, social capital, infrastructure and construction, environmental hazard management, and planning, should be viewed through the lens of these criteria and examples of success. Table 4 identifies broad categories of adaptive actions from the literature reviewed and the factor of resilience they address. Marked cells indicate discussion a specific action type in the literature.

Table 4, Example successful adaptive actions

Suggested adaptive action	Element(s) of resilience addressed	Biagini	Adger	Nelson	Eriksen	Doria
Policies that promote adaptation (e.g. floodplain zoning)	**L, GG, P**	●	●	●	●	●
Educating stakeholders about adaptation options	**E, SC, P**	●	●	●	●	●
Participatory planning and design	**L, GG, SE, E, SC, P**	●	●	●	●	●
Ecosystem conservation/ restoration plans and construction	**L, EH, P**	●	●	●		●
Adaptive infrastructure plans and construction	**L, IC, P**	●	●	●		●
Long term planning at multiple scales	**L, P**		●	●	●	●

Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning

Chapter 4. Methods

To describe strengths and weaknesses and offer insights on the Climate-Adaptive Design (CAD) partnership program, I developed metrics for both resilience and adaptation based on the literature reviewed in Chapter 3. As an ongoing program that could be expanded to other agencies and universities, it is important to have a standardized method of tracking the impact of CAD. These metrics are one approach for evaluating participating communities' resilience and could potentially be utilized in the future to understand how adaptation actions influence their resilience over time.

Measuring Resilience

Before measuring the effectiveness of programs such as CAD at improving community resilience, it is critical to develop a baseline understanding of that community's level of resilience. The following metric was designed to measure the baseline resilience of communities before participating in CAD in the future and potentially for re-evaluate their resilience at a future date after participating in the program and/or implementing CAD designs. Social factors are emphasized in this metric, to act in complement with existing measures that focus primarily on planning and physical factors already used by the Estuary Program (e.g., the CSRP tool).

Figure 2 shows the metric for a given community. The leftmost column lists factors found in the literature, with the description of corresponding measured elements in the adjacent column. Statements were developed to measure stakeholder perception of each factor, listed in the 'Statement' column. A questionnaire asked respondents to rate their

Resilience	Measured element	Statement
Community		
Leadership	Effectiveness of elected leaders	I have respect for the [leader type] and feel they can impact [municipality] in a positive way.
	Environmental issues a priority	I think environmental issues are a priority for [municipality].
	Honestly assesses risks	I think that [municipality]'s government understands climate change risks and is planning for them.
	Ability to leverage outside support	I think [municipality] has the ability to face future challenges related to climate change or knows how to get help with those challenges.
Good governance	Transparency/ communication	[municipality] officials clearly communicate guidelines, plans, and projects to the community.
	Responsive to community concerns	I think [municipality] government is open to concerns and ideas from residents.
	Concern/ consideration for disadvantaged groups	I feel that [municipality] government and residents are concerned about the well-being of disadvantaged groups.
Stakeholder engagement	Engaged and willing to devote time/ effort to projects	I believe residents are engaged in the community and willing to devote time to community projects.
Education	Educated about climate change related plans	I know of plans in [municipality] to deal with climate change.
	Educated about climate change & risks	I think my neighbors know about climate change and its risks.
Social capital	Mutual aid (assist each other in times of need)	In my experience, during a disaster [municipality] residents work together to support and assist each other.
	Businesses/ Nonprofits are active	I have seen business owners, religious groups, and other community groups active in our community.
	Pride in community/ feeling of 'belonging'	I am proud to be a resident of [municipality].
Physical Environment		
Infrastructure	Condition of infrastructure	In my experience, roads, water pipes, and other public facilities are well-taken care of in [municipality].
Environmental hazards	Plans are being made to address environmental hazards (ie brownfields)	I know of plans in [municipality] to deal with possible environmental hazards (such as old industrial land, pollution).
Outlook		
Long term planning	Climate change is being considered in planning/ decision making	I think that Kingston's government understands climate change risks and is planning for them.

Figure 2, Community Resilience Metric

agreement with each statement on a scale from 1 to 5, with 1 indicating strong disagreement and 5 strong agreement.

The resulting questionnaire was piloted with stakeholders from the three communities that have participated in the Climate-Adaptive Design (CAD) program so far. The surveys were distributed via email to nine CAD participants from the Village of Catskill, fifteen CAD participants from the City of Hudson, and twenty CAD participants from the City of Kingston. Because of low response rate, the survey was revised to be shorter and the language of the questions changed according to recommendations from Dillman, Smyth, and Christian (2014).

The revised questionnaire, included in Appendix C, was distributed to the same list of people, excepting those that had already responded. The questionnaire was sent via email from an Estuary Program email known to the respondents. In addition, stakeholders identified by the CAD team as primary coordinators of the process in their community were interviewed to give context on the municipality, better understand interaction between the Estuary Program and participants, and to provide more detail on resilience factors outlined in the metric. Semi-structured interviews were conducted on factors outlined in the metric, with the interviewees invited to discuss additional topics they felt relevant to the CAD program.

Evaluating Adaptation

To track the adaptation of communities and recommend further actions, a metric based on these criteria was developed. The metric tracks adaptive actions by a community, beginning with participation in CAD. Any adaptive projects related to CAD undertaken by each community were listed and categorized. Table 5 shows a sample metric with actions categorized according to which element of resilience they address. Projects are defined as two main types, 'plan' corresponding to Biagini et al. (2014)'s phases of recognition and policy creation, and 'action' corresponding to the building phase.

Table 5, Sample Community Adaptation Tracking

Municipality, Date of course			
Example Actions	**Element(s) of resilience addressed**	**Type of project (plan v. activity)**	**State of completion**
Educate stakeholders about adaptation options through CAD	SE, E	activity	complete - events held
Add a flood overlay district to zoning	L, P	plan	complete - zoning revisions adopted
Waterfront structure renovated to be floodable by private owner	IC	activity	in progress - under construction
Work with stakeholders to build a 'stormwater park'	GG, SE, IC, EH, P	plan & activity	in progress - park is being designed
Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning			

The first three communities to participate in the Climate-Adaptive Design program are analyzed using these resilience and adaptation metrics in tandem, along with interview responses, discussion with Estuary Program staff, and review of student recommendations. Understanding the resilience of participating communities and particular factors that they need to improve can help the Estuary Program and professors target the efforts of CAD. Their cases are described in the following chapter.

Chapter 5. Case Studies

In order to better understand the Climate-Adaptive Design (CAD) program and develop recommendations to improve it, the cases of the three communities who have participated thus far are described. For each community I provide relevant background information, review their participation in the program including major challenges to designing for the sites, and student responses to those challenges. Further, I provide insights to the CAD process and ongoing work within these communities, gained from survey and interview responses and adaptation evaluation conducted during research for this thesis. Finally, I discuss results and analysis between and across the three cases.

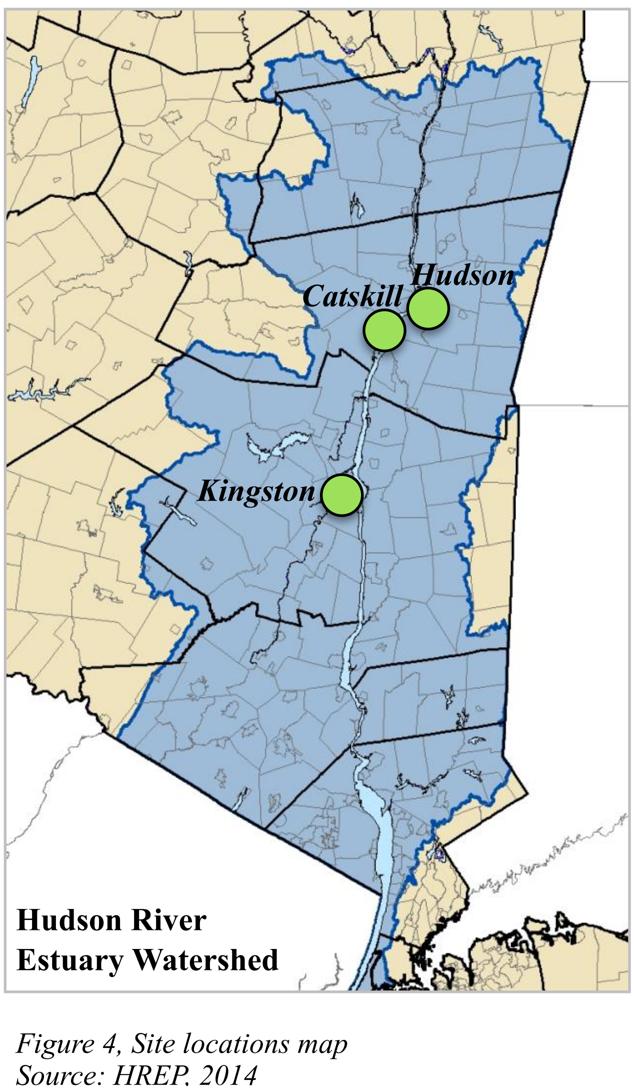

Figure 4, Site locations map
Source: HREP. 2014

To date, the Village of Catskill participated in the Fall semester of 2015, the City of Hudson in the Spring of 2016, and Kingston in Fall 2016 have participated in the CAD program (Zemaitis, 2016). While there are many differences among these municipalities, each faces significant climate change risks. These risks include more frequent flooding from sea-level rise, intense precipitation, stormwater runoff, and storm-surge, along with heat stress and short-term drought (NYSERDA 2014; WRI, 2016). In addition, each of these communities is engaged in ongoing work with the Estuary Program and expressed interest in participating in CAD.

Catskill

The Village of Catskill, NY is located along the western bank of the Hudson River, at the confluence of the Catskill Creek in Greene County. The Village was incorporated in 1806 and is wholly contained within the Town of Catskill, founded in 1788. Governed by an elected Village President and five-member Board of Trustees, the Village has an active Planning Board but no planning staff and no Conservation Advisory Council. As all officeholders are part time and there is limited full-time staff, the village generally has limited capacity to take on new challenges. The Village's location along the banks of the Catskill Creek and Hudson River makes it highly vulnerable to riverine and storm surge flooding that is being exacerbated by climate change-fueled sea-level rise. See Figure 5 (Scenic Hudson, 2017).

Figure 5, Catskill, NY - 36" sea level rise scenario
Source: Scenic Hudson Sea Level Rise Mapper

The historic core of the village is centered on Main Street just up the hill from the creek and connected to it by narrow alleyways (Catskill, 2014; Cerra, 2016). The village has historical significance as the home to famed Hudson River School painter Thomas Cole (1801-1848), and as a 19th century industrial center with factories utilizing the creek for power, cooling, and easy transit both into the Catskill mountains and along the Hudson River to the ports of New York and Albany (Adams, 1996; Buff, 2009). The 1960s ushered in a period of industrial decline in Catskill along with the entire region (Adams, 1996). During this decline, manufacturing, warehousing, and transportation industries located along the Catskill Creek and the Hudson River were abandoned, reducing the Village's tax base and therefore its ability to invest in planning or infrastructure development (Adams, 1996; Zemaitis 2016).

Starting in the early 2000s, the Village began to revitalize its economy and community by linking its arts history and abundant vacant industrial and warehouse space to attract organizations such as the American Dance Institute, theater groups, and creative professionals including artist workspaces created by Etsy (Buff, 2009; Zemaitis, 2016). In addition to a new, arts-based economy, public spaces along the creek are proposed, including parks, waterfront trails, and dining spaces to attract visitors and serve residents (Catskill, 2014; Zemaitis 2016). This revitalization, however, has not been welcome by some residents, resulting in a 'newcomer' versus 'old-timer' dynamic, where long-time residents are seen as resistant to economic development, and new arrivals are accused of gentrification (C1, 2016). There are tensions between the need for renewed growth and improved economic development, and a desire to maintain the character and heritage of the village (C1, 2016; Richardson, 2017).

As it experiences this renewed growth, Catskill faces a range of growing climate risks (NYSERDA, 2014). Catskill is located at the end of the Catskill Creek watershed which includes 416 square miles and is estimated to be the third largest contributor of water to the Hudson River estuary. Intense precipitation falling upstream of the village is causing riverine flooding, while tides and storm surge magnified by sea-level rise brings flood waters up the Hudson River from the Atlantic Ocean (Catskill, 2014; NYSERDA, 2014). Evidence of this impact on Catskill can be found in the storms Irene, Lee, and Sandy that struck in rapid succession between 2011 and 2012 and caused major flooding in the village (Catskill, 2014).

These events focused attention on the growing need to address how water moves through the village, and how to manage development alongside the creek in a way that is responsive to increasing climate risks (Catskill, 2014). The first initiative to address this was the Flooding Task Force, which developed several recommendations for increasing the resilience of Catskill (Catskill, 2014).

In the fall of 2015 Professor Joshua Cerra and the Estuary Program, with the assistance of partners at Cornell Cooperative Extension (CCE) Columbia-Greene, initiated the CAD process in Catskill, bringing undergraduates from his landscape architecture studio course into the community to design options for the downtown area of the village's Catskill Creek waterfront as shown in the aerial photo in Appendix E (Cerra, 2016). Stakeholders invited to participate were Flooding Task Force members and municipal leaders (Zemaitis, 2016). Flooding Task Force members included municipal staff and volunteers, business owners, representatives from CCE Columbia-Greene, and a small number of local residents (Zemaitis, 2016). The community liaison for CAD in Catskill was Nancy Richards, the Community Development Officer for the village (Zemaitis, 2016).

Working in five teams, students proposed a range of options from green infrastructure to floodable park space and structures, and also public engagement features, seeking to create a climate-change adapted waterfront that improves the village's resilience, including economic, social, and environmental factors (Cerra, 2016; Chiaravanont et al., 2015; Zemaitis, 2016). For example, by working with stakeholders the CAD team learned that maintaining an adequate supply of parking spaces was a major village concern. Students addressed this by developing multi-functional open spaces that could provide parking at times of high demand, and a floodable plaza or lawn when parking is not needed (Chiaravanont et al., 2015). Another goal of the stakeholders was to improve access to the banks of the Catskill Creek and create safe ways to interact with the water itself. To achieve this, students proposed strategies such as docks, boardwalks, and terraced plazas, many incorporating accommodations for people with limited mobility (Cerra, 2016; Chiaravanont et al., 2015).

Of nine stakeholders contacted that participated in CAD in Catskill, seven responded to the request to fill out an online questionnaire (n=7), a 77% response rate. The respondents were surveyed using the questionnaire found in Appendix C and their answers scored on the metric as described in Chapter 4. The measured factors are scored on the metric using a scale from 1 (minimal) to 5 (high), resilient capacity as perceived by CAD participants, shown in Table 6. Both the 'Leadership' and 'Long-term planning' factors were scored below 3, indicating that respondents feel long-standing political leaders in Catskill are not impacting the Village positively and the Village is not adequately planning for climate change hazards.

Table 6, Catskill, NY Resilience Factors measured by questionnaire

Factors	Catskill	Average	Difference
Community			
Leadership	2.82	3.69	-0.87
Good governance	3.19	3.77	-0.57
Stakeholder engagement	3.43	3.93	-0.50
Education	3.21	3.20	0.01
Social capital	4.14	4.01	0.13
Physical Environment			
Infrastructure	3.57	3.15	0.42
Environmental hazard mitigation	3.29	3.63	-0.34
Outlook			
Long term planning	2.57	3.48	-0.91

The ‘Social capital’ resilience factor score for Catskill is above 4, indicating that respondents perceive strong business and non-profit activity in the community, and are willing to work together to assist each other or achieve goals.

For most factors, Catskill stakeholders scored their community lower than the other two CAD communities, which may partly be explained by the Village’s limited budget and staff capacity to work on resilience-enhancing measures, and also is evidenced by the unfavorable score of the ‘Leadership’ factor in the metric (Marcell, 2016; NR, 2017; Weiss, 2017). Social capital development in Catskill may be in response to perceived limited leadership from the municipality (Harrison et al., 2016). The infrastructure score is high likely because Catskill is nearly done upgrading their wastewater pipe system (Richardson, 2017; Zemaitis, 2017).

These results match responses in interviews as well as information from Estuary Program staff. Both groups felt that there was not significant leadership on climate change or planning action on the part of the Village before CAD (NR, 2017; Zemaitis, 2017; C1, 2016). According to an interview with Richards (2017), the culture of the village government tends to be in opposition to planning activity even now, with significant objection to studies (the first step in developing successful projects) and a preference for immediate action. The design and visualization process of CAD was an important step in the process of getting the municipality to begin considering adaptation and resilience-building but there may be considerable work left in promoting the value of long-term visioning and planning within the Village (C1, 2016; Richards, 2017; Zemaitis, 2017).

Despite the Village's low resilience metric score for municipal leadership, Catskill has the clearest links between CAD and adaptive actions undertaken. Table 7 shows these successful adaptation actions since participating in CAD. Each action is listed in a row and the area(s) of resilience the action focuses on are identified. An example is the new The American Dance Institute (ADI) headquarters project 'The Lumberyard' that is currently being developed along the east bank of Catskill Creek. ADI found designs showing floodable outdoor performance space, and options for flood walls that act as seating during sunny weather, particularly interesting and has hired a CAD student to further develop their design into a site plan incorporating climate adaptive elements (C1, 2016; Zemaitis, 2016).

Table 7, Catskill, NY Adaptive actions since CAD participation

Catskill, NY Fall 2015			
Adaptive Actions	**Element(s) of resilience addressed**	**Type of project (plan v. activity)**	**State of completion**
Educate stakeholders about adaptation options through	SE, E, SC	activity	complete - events held
ADI (Lumberyard) development of adaptive performance space	SC, IC, P	plan & action	ongoing
Marina building flood-proofing	IC	activity	complete
Participation in sea-level rise learning groups	L, E, SC, P	plan	in progress
Green infrastructure in alleys	L, IC, EH	activity	on hold
Flood resilience zoning review	L, EH, P	plan	in progress
Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning			

At a municipal level, Catskill is participating in a set of workshops called the 'Hudson Sea Level Rise Learning Groups' facilitated by the Estuary Program, Scenic Hudson, and the Consensus Building Institute as a follow on to CAD and the Flooding Task Forces. A zoning code review with recommendations to change code for flood resilience has also recently been completed by a consultant, though it is uncertain whether the recommendations will be adopted (C1, 2016; Richards, 2017).

In an effort to actively implement in addition to plan, a proposal to install green infrastructure in two alleys currently being debated within the community is based on a CAD student design (C1, 2016; Richards, 2017). This project could be a model for the region, but is currently on hold due to the objections of several residents who were not involved in CAD (Richards, 2017; Zemaitis, 2017). Residents are concerned about the impact of reducing the width of the alley on traffic flow and trash pickup, and are currently unwilling to discuss the proposed changes (Richards, 2017). Because Catskill has not engaged stakeholders about CAD after its completion many have not yet had the opportunity to understand recommendations from students, especially residents who were not adequately represented in the process (Richards, 2017; Zemaitis, 2017). This highlights the need for engagement in planning to empower stakeholders (Luyet, 2012; Folke, et al., 2002).

While there were several participants in the CAD process, they were drawn primarily from local non-profits, state agencies, and business owners that had participated in the Flooding Task Force (Cerra, 2016; Richards, 2017). Because of a lack of outreach to the wider community, many residents did not learn about CAD until after the semester had ended (Zemaitis, 2016; Richards, 2017). This has led to a lack of understanding and enthusiasm for moving forward with CAD recommendations (Marcell, 2016; Richards, 2017). However, those that did participate have taken action. The fact that those who did participate were educated about a broad range of adaptation options, and energized to pursue ongoing work along the creek is encouraging (C1, 2016).

Hudson

Hudson, New York sits on the eastern shore of the Hudson River, approximately 120 miles north from New York City, and is impacted by daily tides. In 1785 Hudson was chartered, splitting from the neighboring Town of Claverack. The City is small, just under 3 square miles in area with population of almost 7,000. The City is governed by a Mayor and Common Council with an active Conservation Advisory Council. Hudson has no planner on staff but its Planning Board is active. The majority of Hudson's current risk from climate change is from sea-level rise and storm surge flooding of the Hudson that will inundate existing marshland and the Amtrak rail line, along with both existing and proposed industrial, commercial, and recreational space, see Figure 6 (Scenic Hudson, 2017).

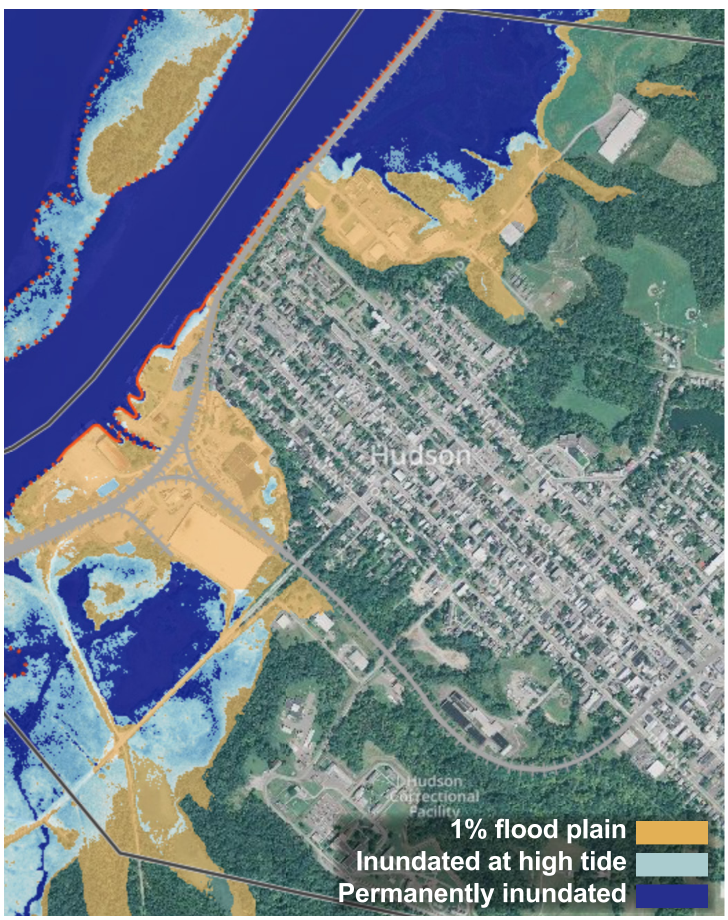

Figure 6, Hudson, NY 3 feet of sea level rise scenario
Source: Scenic Hudson Sea Level Rise Mapper

Hudson has a historic urban core, and its waterfront housed a thriving whaling industry in the late 18th century (Adams, 1996; Buff, 2009). Later, Hudson became a destination for steamships of vacationers from New York City arriving via the Hudson River (Buff, 2009). Buildings in Hudson include a blend of preserved historic structures and modern housing, and the City is known for its art and antique galleries (Buff, 2009). The downtown area of Hudson along Warren Street is disconnected from the waterfront by a steep hillside, protecting most of the residents from the significant flood risk directly along the river (H1, 2016). Currently, the Amtrak station with direct service to Manhattan, and the Basilica, an industrial building converted to performance space, anchor the waterfront along with a public park and an industrial dock owned by A. Colarusso & Son, Inc (Buff, 2009; Zemaitis, 2016).

In the past twenty years revitalization and renovation along the uphill main road in Hudson, Warren Street, has been a catalyst for a steady influx of wealthy residents, many buying weekend and vacation homes in Hudson or relocating from Manhattan (H1, 2016). In contrast, neighborhoods near the river tend to have a population of lower income immigrants and people of color, continuing a pattern of settlement begun during the whaling industry where workers lived near the docks while the wealthy lived uphill, and perpetuated through urban renewal in the 1970s when subsidized housing developments were placed near the river (H1, 2016; Marcell, 2016). As the residents in these areas are at a much higher risk from flooding than their uphill neighbors and have lower capacity to relocate, climate change in Hudson has environmental justice implications (H1, 2016; Marcell, 2016).

Adjacent to these residential areas is the core of the project site as shown in the aerial photo in Appendix E including the Amtrak station, Basilica, a commercial port, a marina, and abandoned industrial brownfields. The South Bay, a globally rare freshwater tidal marsh created by the building of the train tracks over 100 years ago is also located along Hudson's banks south of the industrial site and was incorporated (Zemaitis, 2016). Over the past decade, many proposals have been made to redevelop Hudson's waterfront and link it to the downtown both economically and physically. Unfortunately, most of these proposals have been the victim of political and budgetary challenges and further waylaid by flooding events (H1, 2016; Zemaitis, 2016). In addition, potentially contaminated soils on former industrial brownfield sites and uncertain climate predictions have made development less attractive. Despite these issues, the city sees the banks of the Hudson River as a potential economic engine, with profit to be made from the sale or lease of city-owned vacant land and buildings in the area, and economic growth from the renewed activity the redeveloped parcels would hopefully bring (H1, 2016; UDell, 2016).

The community liaison for Hudson was Jonathan Lerner, a local resident and chair of Hudson's Conservation Advisory Council. He learned of the CAD studio process in nearby Catskill and approached HREP staff about bringing the course to Hudson (Zemaitis, 2016). Jonathan was the primary recruiter for participants in the program with assistance from HREP staff (Zemaitis, 2016). Students worked primarily with business owners including a representative from the owner of the industrial port, A. Colarusso & Son, municipal representatives, state and non-profit partners, and some residents to develop proposals for Hudson (H1, 2016). However, the list of participants in CAD did not include waterfront residents or those elected officials representing them (H1, 2016). This raises environmental justice concerns as those with seemingly the most at stake lacked a voice in the process (H1, 2016; Marcell, 2016).

Student designs dealt with the ecological challenges of maintaining or improving the ecological function of the South Bay marsh with sea level rise by expanding green and protected space to allow the marsh to migrate upland (Chirico, A. et al., 2016). The adaptive reuse of existing abandoned buildings, and the potential for raising or eliminating the Amtrak train tracks—predicted to be inundated daily at high tide within the next fifty years— were other options examined in students' work (Chirico, A. et al., 2016; NYSERDA 2014). In Hudson, the final design boards were presented in an open house at the city's main library, and later presented and placed on public display in the historic Hudson Opera House on Warren Street.

Of 15 CAD participants in Hudson contacted, 8 responded to the request to fill out an online questionnaire, a 53% response rate. The respondents were surveyed using the questionnaire found in Appendix C and their answers scored on the metric as described earlier in this chapter. The measured factors are scored on the metric using a scale from 1 (minimal) to 5 (high) resilient capacity, as perceived by CAD participants. Table 8 shows the community resilience scores for Hudson along with an average of stakeholder scores from all three communities surveyed. As shown in the table, the metric score for both 'Stakeholder engagement' and 'Social Captial' are above 4, indicating that survey respondents felt that Hudson stakeholders are engaged and that there are strong relationships within the community. This may in fact be true for a segment of the population, however interviews and conversation with HREP staff reveal concerns about underrepresentation of minorities and lower income populations in community processes (H1, 2016; H2, 2017; Zemaitis, 2016). This highlights the need for consideration of the surveyed population when analyzing results. Since the respondents are those that participated in CAD, likely the most engaged segment of the population, they therefore are most likely to have a positive impression of stakeholder engagement within the community.

Table 8, Hudson, NY Resilience Factors measured by questionnaire

Factors	Hudson	Average	Difference
Community			
Leadership	3.81	3.69	0.12
Good governance	3.92	3.77	0.15
Stakeholder engagement	4.50	3.93	0.57
Education	2.56	3.20	-0.64
Social capital	4.21	4.01	0.20
Physical Environment			
Infrastructure	2.63	3.15	-0.52
Environmental hazard	3.38	3.63	-0.25
Outlook			
Long term planning	2.88	3.48	-0.61

Conversely, the metric score for ‘Education’ was below 3, meaning respondents believe that Hudson’s residents are not well educated about climate change risks and existing plans to deal with those risks Hudson, which may be partly describing the less involved segments of the population discussed in interviews. According to interviews, while stakeholders likely were aware of climate change in the past, it was on a more global level and they had not understood how it could impact Hudson (H1, 2016; H2, 2017). CAD expanded participants’ awareness to include local impacts, but many people in the community were not involved or informed of CAD designs (H1, 2016; H2 2017). Survey and interview responses indicate that despite public presentations of design boards and the galvanization of some public officials, in the city overall, there seems to be limited knowledge of the CAD designs or program (H1, 2016; H2, 2017; Weiss, 2017b).

'Long term planning' and 'Infrastructure' both are scored below a 3, indicating respondents do not feel that Hudson is engaging in appropriate planning for future climate change impacts, and not managing infrastructure well. Both of these are serious barriers to building resilience and adapting to climate change and have been issues in Hudson for many years, but the City has begun to address these issues, as seen in Table 9 highlighting successful adaptive actions taken by the City since participating in CAD. Each action is listed in a row and the area(s) of resilience the action focuses on are identified.

Table 9, Hudson, NY Adaptive actions since CAD participation

Hudson, NY Spring 2016			
Adaptive Actions	**Element(s) of resilience addressed**	**Type of project (plan v. activity)**	**State of completion**
Educate stakeholders about adaptation options through CAD	SE, E, SC	activity	complete - events held
Dunn warehouse planning	GG, SE, P	plan	in progress
LWRP writing	L, GG, SE, E, EH, P	plan	in progress
Natural resources inventory	E, SC	plan	in progress
CRB workshop with TNC	L, GG, SE, EH, P	activity	complete - events held
Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning			

CAD's process of taking old proposals into account while visioning new options, and the students' fresh perspective helped to renew previous efforts to develop a Local Waterfront Revitalization Plan (LWRP) for the City of Hudson, and encouraged the city to apply for a grant from HREP to complete the Natural Resources Inventory (NRI) being undertaken by the city's Conservation Advisory Council (CAC) (H1, 2016). This grant was awarded in 2016 and is enabling the CAC to not only complete their NRI but also survey and evaluate their street trees (Zemaitis, 2017).

The final design boards and information provided to the city during CAD have also been used to inform discussions about potential development along the waterfront, specifically in regard to the city-owned Dunn Warehouse property that was within the site studied by CAD students (H1, 2016; H2 2017). The site is currently the subject of a Request for Proposals (RFP) for long-term lease or sale (H1, 2016). However, this process is an example of one where ideas and information gained from CAD had to be continually reintroduced during discussions (H1, 2016). In this case, a lack of resident knowledge and support may be an obstacle to achieving adaptive action since officials tend to prioritize issues that are important to their constituents (H2, 2017). It remains to be seen what the outcome of the RFP process is and if it will take CAD recommendations into account.

Unlike Catskill and Kingston, Hudson had not participated in a Flooding Task Force before participating in CAD, and engaged in comparatively less planning with less technical assistance from HREP than the other two communities. CAD was a gateway for Hudson to receiving increased technical and funding assistance from the HREP. This increased support includes a grant and assistance to pilot the New York implementation of ‘Community Resilience Building’ (CRB) workshops by the Nature Conservancy (TNC).

Kingston

Kingston, New York is located along the western shore of the Hudson River, at its confluence with the Rondout Creek. Originally founded by the Dutch in the mid 17th century and called.

The modern City of Kingston was incorporated in 1805 and has a population of approximately 29,000. Governed by a Mayor and Common Council with a two-person planning staff and active boards including its Conservation Advisory Council, Planning Board, and 'Climate Smart Kingston' taskforce.

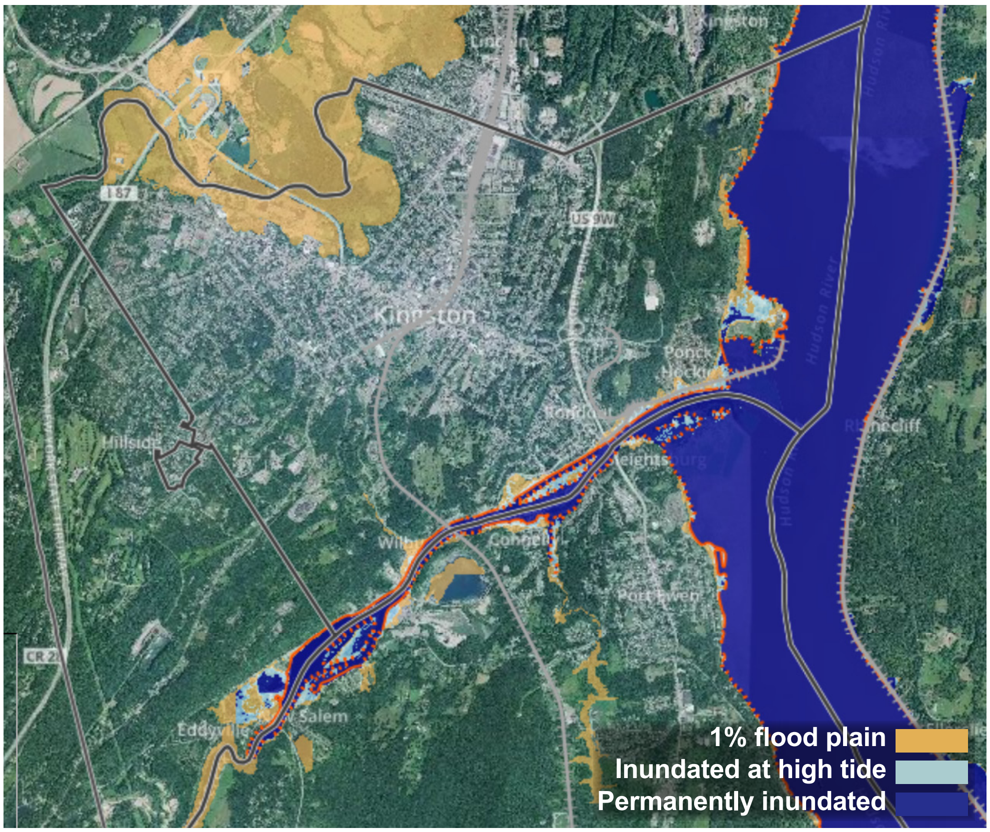

Figure 7, Kingston, NY 3 feet of sea level rise scenario
Source: Scenic Hudson Sea Level Rise Mapper

The main climate change risks facing the City are related to flooding; the Rondout Creek which has a watershed of over 1,100 square miles and stretches both west into the Catskill Mountains and south with the Wallkill River into New Jersey. The Creek is often flooded due to intense precipitation, and also experiences tidal fluctuation and storm surge from the Hudson, both of which are expected to increase with climate change, see Figure 7

(Scenic Hudson, 2017) (Kingston, 2013; Zemaitis, 2016). In addition, heat stress and short term drought are also becoming concerns for the City as the climate shifts (Zemaitis 2016).

The modern City of Kingston is the product of merging two historic towns, Kingston with its relatively well-off Stockade District, and Rondout with its docks and shipping industry along the Rondout Creek (Adams, 1996; Buff 2009). The merged city has a settlement pattern similar to Hudson, of industry and workforce housing located on easily flooded land along the Creek and Hudson River, and wealthier residents living safely uphill (Adams, 1996; Buff 2009). Urban renewal in the 1970s and 1980s destroyed many of the historic structures along the Creek, replacing them with now partly demolished low-income housing projects, and paving over several vacant industrial lots (Adams, 1996; K1 2016).

Along the bank of the Creek, marinas, restaurants, and vacant lots make up the land uses, including a vacant man-made island called Island Dock. The bank of the Rondout has been the subject of much discussion over the years about how to best utilize the land including the most recent effort, the Hudson Riverport Plan, a Brownfield Opportunity Area (BOA) study released by the city (Kingston, 2015). The plan calls for varying and extensive development along the bank, from boutique hotels to a visitor center and marina facilities (Kingston, 2015). This plan was completed under a previous mayoral administration, and is currently being evaluated for feasibility.

The community liaison for Kingston is the chair of the Climate Smart Kingston Committee. Stakeholders participating in CAD included property owners within the project site, municipal staff, elected officials including Mayor Noble, and HREP staff that live in the city of Kingston. As the majority of the project site is public park and commercial property, there were few residents of the site to reach out to, and neighbors and users of the park were not represented during the design process though the alderman representing the area was in attendance at the final open house.

During the CAD course in the fall of 2016, Professor Cerra's students examined a stretch of the Rondout including Island Dock and along the bank of mainland across from the island, Block Park and an adjacent marina as shown in the aerial photo in Appendix E. Students were faced with a particularly difficult challenge, as Island Dock and Block Park are threatened by three types of flooding; riverine, tidal surge, and overland stormwater runoff (Kingston, 2013; Zemaitis, 2016). The site is also very low-lying and according to NYSERDA (2014), medium to high rates of sea level rise (approximately 36" - 48") will cause virtually the entire site to be inundated daily by 2080.

Block Park is used frequently for softball leagues, and the marina is an important economic and tourist draw. The marina adjacent to the park, Hideaway Marina, is privately owned and an economic engine for the area (Noble, 2016). It attracts sail boats because of its safe harbor and proximity to the Hudson (Zemaitis, 2016). Island Dock is a privately-owned vacant brownfield needing remediation of contaminated soils, and repairs to the shoreline treatments currently preventing the island from eroding away (Kingston, 2013 & 2015; Zemaitis, 2016). Notably, the Hudson Riverport Plan calls for a land swap between Block Park and Island Dock, with only the softball field remaining on the mainland (Kingston, 2015). Because public parks enjoy special protection in the state of New York, this swap would be extremely difficult to accomplish, and is unlikely to occur (K1, 2016; Marcell, 2016).

As students analyzed sea-level rise predictions and began to understand the extent of predicted inundation at this site, especially on Island Dock, several of the six teams chose to allow the island to be submerged, focusing protections and development on the mainland (Anderson, G. et al., 2016). Some proposed designs cut channels through the island, using the fill material to raise the height of adjacent areas, with the long-term effect of creating a small cluster of islets (Anderson, G. et al., 2016). Others proposed using Island Dock as a laboratory, since its shoreline will be inundated sooner than many locations in the Hudson Valley, it could become a location to study methods of encouraging marsh accretion and shoreline stabilization (Anderson, G. et al., 2016). Recreational access to the water was incorporated in several designs, through installations such as kayak docks, and boardwalks through marshland (Anderson, G. et al., 2016).

Maintaining vital access along Abeel Street, located along the Rondout Creek, was addressed by either raising the road on an earthen berm or causeway, or in one design, creating a bridge (Anderson, G. et al., 2016). Development proposals were restricted to areas along a raised Abeel Street, or in locations further upland, out of the flood plane (Anderson, G. et al., 2016). To address stormwater running off from adjacent roadways and hills, several students proposed wetlands and swales that slow and treat the water before it enters the Rondout Creek.

Links to Kingston's West Strand district and beyond were shown by extending the current waterfront promenade, and sidewalk and streetscape improvements adjacent to the site (Anderson, G. et al., 2016). These methods to improve travel along the waterfront and better integrate the site into the transportation network of the city were in response to stakeholder concerns about the safety and long-term viability of the roads and walkways in the area (Zemaitis, 2016).

Of 20 contacted stakeholders who participated in CAD in Kingston, 12 responded to the request to fill out an online questionnaire, a 60% response rate. The respondents were surveyed using the questionnaire found in Appendix C and their answers scored according to the metric as described earlier in this chapter. The factors are measured within the metric on a scale of 1 to 5, with 1 indicating minimal and 5 high resilient capacity. As seen in Table 10, of the tree municipalities, Kingston scored well overall on a social measure of resilience, with no factors scoring lower than 3.25.

Table 10, Kingston, NY Resilience Factors measured by questionnaire

Factors	Kingston	Average	Difference
Community			
Leadership	4.13	3.69	0.43
Good governance	4.00	3.77	0.23
Stakeholder engagement	3.83	3.93	-0.09
Education	3.63	3.20	0.42
Social capital	3.81	4.01	-0.21
Physical Environment			
Infrastructure	3.25	3.15	0.10
Environmental hazard	4.00	3.63	0.37
Outlook			
Long term planning	4.42	3.48	0.94

The two categories that are notable for scoring above 4 are ‘Leadership’ and ‘Long term planning,’ indicating that the respondents believe leaders in the City are well respected and able to affect positive change and that the City is more than adequately planning for climate change (Weiss, 2017c). Interview responses indicate that this result is accurate, with one respondent calling Kingston a “City of Plans” (K1, 2016; RI, 2017). However, ‘Infrastructure’ received the lowest score for the City, meaning there is concern that roads, wastewater treatment plants, power lines, and other public services are not in good repair and are vulnerable to risks from climate and other hazards.

Table 11 shows successful adaptation actions undertaken by Kingston since participating in CAD. Each action is listed in a row and the area(s) of resilience the action focuses on are identified. Continuing their strength in planning, since CAD completed in December of 2016, Kingston has initiated a natural resources inventory (NRI) and is participating in the Hudson Sea Level Rise Learning Groups with Catskill and other municipalities. The NRI process will complement their existing Comprehensive Plan and Brownfield Opportunity Area Plan “Hudson Riverport Plan” and provide essential habitat and ecological data to inform future development in the city.

Table 11, Kingston, NY Adaptive actions since CAD participation

Kingston, NY Fall 2016			
Adaptive Actions	**Element(s) of resilience addressed**	**Type of project (plan v. activity)**	**State of completion**
Educate stakeholders about adaptation options through CAD	SE, E, SC	activity	complete - events held
Natural resources inventory	E, SC	plan	in progress
Participation in sea-level rise learning groups	L, E, SC, P	plan	in progress
Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning			

As the most recent participant in CAD, Kingston may need more time to put student design ideas into action. The city has several active construction projects not related to CAD that are currently top priority. When these projects, many of which are adaptive including installing a bicycle ‘rail-trail’ and green infrastructure and bike lanes along Broadway in another part of the city, are completed there may be greater capacity for acting on CAD student recommendations.

Discussion

Initial survey response rates in all three communities were low, with three or fewer respondents from each community. There are three factors that may have contributed to this low response rate. First, the questionnaire was sent from an email that was unfamiliar to respondents and may have gone unopened. Second, over the course of survey development the original questionnaire became several pages long which may have been daunting (Zemaitis, 2016). Third, some of the statements may have discouraged response, due to phrasing that implied expert knowledge (Dillman, Smyth & Christian, 2014). Therefore, the questionnaire was revised to be shorter, use clearer language incorporating fewer assumptions, and resent from a familiar email address. These changes resulted in a significantly higher response rate.

Because the questionnaire, found in Appendix C, is relatively short and divided into sections, and is easily scored using the metric, it is hoped that the measurement process can be repeated in whole or in part to evaluate the ongoing impacts of the Estuary Program and other agencies and organizations as they work to improve resilience in the Hudson Valley. The tools may also be used as a model for other regions, adjusted to be relevant in local contexts.

Ideally this survey process would have occurred before CAD to establish a baseline understanding of a community's resilience, in this case the survey was after the community participated. It is therefore not possible to use this metric to track the direct impact of CAD on community resilience. In fact, it would be impossible to attribute all changes solely to CAD, as these communities and stakeholders are engaged in many activities that can impact community resilience. Despite this, it is still valuable to evaluate these factors to guide future work with the communities. While taking into account differences in capacity and context between the communities, useful insights can be gained by comparing their resilience metric scores and adaptive actions.

The resilience factors are measured within the metric on a scale of 1 to 5, with 1 indicating minimal and 5 high resilient capacity. Table 12 illustrates results across the three communities, with the average stakeholder score shown in the rightmost column. Catskill and Hudson both are both perceived to be lacking in 'Long-term planning' for climate impacts, while Kingston has perceived strength in this. The average score for 'Education' is among the three lowest scores along with 'Infrastructure,' and 'Long term planning.' As these are cross-boundary issues, they may present areas for the Hudson River Estuary Program to focus efforts.

Despite stakeholder engagement perceptions scoring relatively well on the metric, the audience for Climate-Adaptive Design boards or proposals has so far been limited (C1, 2016; H1, 2016; K1 2016). According to survey and interview responses, residents and business owners in or adjacent to the project sites, especially minority populations and those not typically involved in community processes, have only been engaged in limited ways (C1,

Table 12, Resilience metric scores across CAD participating communities

Factors	Catskill	Hudson	Kingston	Average
Community				
Leadership	2.82	3.81	4.13	3.69
Good governance	3.19	3.92	4.00	3.77
Stakeholder engagement	3.43	4.50	3.83	3.93
Education	3.21	2.56	3.63	3.20
Social capital	4.14	4.21	3.81	4.01
Physical Environment				
Infrastructure	3.57	2.63	3.25	3.15
Environmental hazards	3.29	3.38	4.00	3.63
Outlook				
Long term planning	2.57	2.88	4.42	3.48

Dark shaded cells are the three highest scored factors, indicating greater perception of resilience while light shaded cells are the three lowest scored factors. Outlined cells are the three factors with the lowest average score.

2016; H1, 2016; K1 2016; Weiss, 2017a, b, c). This lack of outreach seems to be a product of the challenging task of engaging populations who may not be well-integrated into community discussions, combined with concern among municipal liaisons and CAD organizers that having too many voices could over-complicate the process (Cerra 2016c; K1, 2016; C1, 2016; Zemaitis, 2016). Limited municipal capacity in many Hudson Valley communities adds difficulty to this essential task of reaching out to and incorporating stakeholders (C1, 2016; K1, 2016).

While stakeholders and other participants may have been aware of climate change before participating in CAD, the program seems to have expanded their understanding of climate change impacts, particularly at a local and regional scale (C1, 2016; H1, 2016). Further, participants gained knowledge of adaptation options that can be implemented in their community (C1, 2016; H1, 2016). Municipal leaders have been educated about adaptation options, both near and long-term available to them, and provided with graphical outreach and educational tools in the form of final design boards (C1, 2016; Zemaitis, 2016).

However, the metric indicates that education about climate change continues to be seen as a weakness, and these newly educated leaders and CAD participants should be encouraged to share their learning with their communities. There is a positive in that local participants in CAD have been motivated to take at least first steps toward adaptive action, including planning green infrastructure installation in Catskill and restarting the Local Waterfront Revitalization Planning process in Hudson.

Table 13 shows the number of adaptive actions taken in each potential area of focus in communities since participating in CAD. Infrastructure and Construction was identified by stakeholders as a factor needing more effort in their communities, and so far only Catskill has begun to address this. Catksill and Hudson have undertaken planning, a resilience factor stakeholders in those communities scored comparatively low. Variations among the communities should be considered when reviewing these results; Kingston has a long history of addressing climate change and environmental issues in its planning processes and may therefore need to do less work on planning than the other two communities. All three have worked on education, the third resilience factor that received a comparatively low score from stakeholders. Across the three communities, the majority of actions undertaken thus far have centered on education, engagement, or social capital with less actions to adapt the physical environment.

Table 13, Adaptive actions across CAD communities

Catskill, Hudson, and Kingston, NY Fall 2015 - Fall 2016										
Community	**L**	**GG**	**SE**	**E**	**SC**	**IC**	**EH**	**P**	**Type of projects (plan v. activity)**	**State of completion**
Catskill	2	0	1	2	3	3	2	3	plans & activities	in progress
Hudson	2	3	4	3	2	0	2	3	plans & activities	in progress
Kingston	1	0	1	3	3	0	0	1	plans & activities	in progress
Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning										

Climate change is rapidly shifting the natural environment, and communities are facing great challenges in adapting their built environment to these shifts. Provided greater numbers of stakeholders can be engaged, the participatory planning and design process of CAD can help communities come together to meet these challenges. Incorporating design and visualization of adaptation and resilience, Climate-Adaptive Design (CAD) has the potential to make necessary climate adaptation part of a positive, growth-oriented process that increases the resilience of a community physically through building projects, and socially through education and cooperation.

Chapter 6. Policy Recommendations

As the Climate-Adaptive Design (CAD) program continues to engage with communities in the Hudson River estuary watershed, the following recommendations to improve the program should be considered. These recommendations have been developed based both on primary research results and best practices and strategies drawn from the literature, focusing on those solutions that the Hudson River Estuary Program can most directly impact. I have three primary recommendations. First, I recommend that the resilience survey and metric designed for this research project be used in conjunction with existing state resilience measures for future work by the Estuary Program. Second and more specifically for the CAD program, though also valuable for other efforts, I recommend expanding outreach and improving stakeholder engagement. Third, in order to promote implementation of viable CAD student recommendations, the Estuary Program should target technical support, funding mechanisms, and linking to existing State programs to CAD designs. I provide detail on these recommendations below, with specific examples or strategies for implementation.

Resilience survey and metric

As the Estuary Program works to build resilience in Hudson River estuary watershed communities, it is taking on the important task of evaluating its efforts. Currently, a tool being used to evaluate the climate change resilience of communities is called the ‘Climate Smart Resilience Planning Tool’ and it predominantly focuses on the existence of planning documents and physical projects (often infrastructure) installed that improve resilience. While physical projects and documents are often easier to track or measure, there is consensus that social factors are key to creating resilient communities (Adger, 2003; Harrison et al., 2016). To address the social component of resilience, the survey and metric developed for this research are designed to be brief, flexible, and relevant to the concerns of municipalities in the Hudson River estuary watershed.

To perform a controlled study of CAD efficacy, the Estuary Program could use this survey and metric to evaluate several communities both before and after CAD and include communities that did not participate as controls. This effort could enable more definitive documentation of the impact of CAD. Using these tools can help the Estuary Program gain insight into social factors and therefore develop a more holistic understanding of resilience within the estuary and how it evolves over time. This insight can guide ongoing agency work. Scoring can be weighted for priority factors, and survey questions adjusted to accommodate the shifting needs of the agency. Further, this tool can identify knowledge gaps between physical projects and planning work, and perceptions of stakeholders, another method to guide agency work.

Expand outreach and stakeholder engagement

As discussed within the case studies in the preceding chapter, a majority of participants surveyed and interviewed from all three communities felt that a greater number and diversity of stakeholders would improve students' learning during CAD as well as the usefulness of recommendations to communities (Weiss, 2017; Richards, 2017; H1, 2016). Similar comments were made during conversations with Estuary Program staff (Marcell, 2016; Zemaitis, 2016). CAD has the potential to be a powerful outreach tool as it works toward the goals Sheppard (2015) describes, engaging stakeholders in a process of participatory design, and integrating visualization to improve planning and participant dialogue. An essential component to improving outreach is a clear strategy for doing so. As discussed by Luyet et al. (2012), stakeholder identification and recruitment is an essential first step.

To begin that process, it is recommended that an advance meeting of Estuary Program staff, municipal liaison, the alderman or board member representing the selected site, and the course professor, attend an in-person planning and strategy meeting approximately six weeks before the course is intended to begin. At this meeting a schedule for site visits should be set, and options for locations of site visits determined. Estuary Program staff and the course professor should also obtain information particular to the community, including environmental justice concerns, groups and businesses that may be open to participating, development plans, and constituent groups that may have been marginalized from public processes in the past (Luyet, et al., 2012). Outreach efforts will necessarily vary between municipalities, however local media and organizations such as churches, social clubs, and sports clubs are examples of potential partners that should be identified and contacted before the CAD course begins.

Attendees should also develop a list of all stakeholders that live in and around or use the site and recommended strategies for reaching out to that particular entity. This will allow meeting attendants to identify key stakeholders and develop tailored recruitment strategies. A streamlined description of the program for use in calls and discussions, along with promotional and explanatory print and web material should be developed to distribute and utilize during this effort. While some recruitment may be done by elected leaders and Estuary

Program staff, there is an opportunity to draw on Cornell Cooperative Extension (CCE) staff who have ongoing contracts for outreach and work extensively within their communities (Zemaitis, 2017).

During this process, care should be taken to incorporate a diverse array of participants from residents to business owners to minorities. A broad range of communication techniques including email, news media, phone calls, canvassing, posting to social networks and texting should be used. Outreach materials and communication should be designed to provide basic information and encourage attendance at CAD events, with the goal of overcoming barriers from simple lack of knowledge about the program, to mistrust and disenfranchisement (Burch et al., 2010; Luyet et al., 2012). Giving voice to multiple viewpoints and avoiding prioritizing one set of stakeholders over another will result in more meaningful participation and therefore more meaningful student designs (Luyet, 2012; Richards, 2017; Zemaitis, 2016).

A simple strategy to increase attendance and participation in CAD is to hold some events outside of work hours. Hudson, NY did host a public event after the designs were complete on a Sunday that was well received but did not increase participation since the semester was over, and such an event has not been replicated in either Catskill or Kingston (H1, 2016; Richards, 2017). Holding one of the two CAD events on a weekend or in the evening should be considered to allow a broader array of stakeholders to attend, particularly those residents of the area who may not work nearby.

All three municipalities that have participated in CAD to date have done little to communicate with the broader public and engage their community in conversation about the student designs after the semester ended (Richards, 2017; C1, 2016; H1, 2016; K1, 2016). Notable exceptions have been window displays in Catskill and the one-day event in Hudson, but these have been limited in scope (C1, 2016; H1 2016). HREP should develop a set of recommendations and provide guidance to municipalities on what to do with the student designs once the semester is over, and encourage the use of these visual products to develop conversations around the futures they envision.

Support implementation of CAD recommendations

Continuing the conversation inspired by CAD should also include discussion of planning and implementation options within the municipality and support for this by Estuary Program. There are several mechanisms through which staff can facilitate this work, from follow-up conversations with municipal leadership to promoting action through funding mechanisms. Each community will have particular student design ideas and recommendations or barriers to implementation that will need to be evaluated before any action can be taken, and technical assistance to communities in fostering this evaluation can be provided by State agencies.

Municipal staff and volunteers engaged in long-term planning processes should be made aware of the CAD designs, and ideally educated about the process if they were not involved during the course. It is particularly important to educate members of Planning and Conservation Boards or Councils, Aldermen, Economic Development officers, and others working within and in conjunction with the municipality about CAD recommendations and discuss their implications. Insight from these individuals is important to determine how and if those recommendations can be integrated into ongoing planning. Estuary Program staff should foster this discussion which will work in concert with wider post-CAD community outreach efforts discussed above, but involve greater detail and engagement with staff, or even CAD students if possible.

While it is important to promote long-term thinking and strive for aspirational futures, there is high potential for many student recommendations and designs to include phasing plans for gradual implementation. Students and Professor Cerra should be encouraged to continue promoting this approach, and consider developing narratives or visuals about temporary demonstration projects such as “pop-up green infrastructure” using low-cost materials and volunteer labor that could test elements of designs, increasing ‘buy-in’ and making the students’ recommendations feel more achievable to municipalities (Richards, 2017; H1, 2016; K1, 2016, Weiss, 2017). Local high school and community college students could be part of these volunteers, as part of internships and coursework, or through community service programs.

The Hudson River Estuary Program and the Department of Environmental Conservation (DEC) can play a role as funders for implementing CAD designs, particularly through their capacity as grantors. For example, ‘Sustainable Shorelines’ and ‘Trees for Tributaries’ programs that both improve the resilience of river and stream banks. Further, in awarding grants related to implementation, both agencies may be able to request reporting from communities that participated in CAD to determine if they are utilizing the designs, and reward those that do. The ‘Climate Smart Communities’ program is a first step toward this in that it rewards communities with higher grant application scores for taking specific actions that are climate adaptive, virtually all of which overlap with CAD designs.

The policy recommendations described emphasize developing knowledge within the Estuary Program about the social aspects of climate resilience, expanding stakeholder engagement, and supporting implementation of CAD student proposals. By building on the research and survey effort of this thesis to understand social aspects of climate change resilience, the Estuary Program can improve their understanding of those factors and their work with estuary communities. Expanding stakeholder engagement will increase education of stakeholders as well as improve the students' and staff's understanding of the needs of communities, enabling them to develop better design and policy options to serve community needs (Luyet et al., 2012; Sheppard et al., 2008). Finally, providing municipalities that often have limited staff and financial capacity with technical assistance and funding for implementation where possible will improve adoption of CAD recommendations.

Chapter 7. Conclusion

Climate change is a reality that we will be forced to address, either proactively or reactively (Nelson, 2011). Adaptation to this change will be mandatory globally, and the Hudson River Estuary in particular will require significant adaptive efforts because of its vulnerability to sea-level rise and stormwater flooding among other impacts (Nelson, 2011; NYSERDA, 2014; Zemaitis, 2016). By encouraging communities to discuss climate change adaptation options, the Climate-Adaptive Design (CAD) program is an important tool in the suite of programs offered by the Hudson River Estuary Program. CAD brings visualization not only of projected climate impacts but also of potential ways to deal with those impacts to stakeholders (Zemaitis, 2016). The premise of CAD is that providing imagery and working with design both makes regional climate impacts clearer, and enables communities to see adaptation as achievable (Cerra, 2016c; Zemaitis, 2016).

Using adaptation to build the resilience of communities is a strategy advocated throughout the literature, as is the use of visualization (Sheppard, 2015). Experts further emphasize the importance of engaging stakeholders in participatory design and visualization to build social adaptive capacity and resilience (Burch et al., 2010; Luyet et al., 2012). By working with students, CAD builds resilience further, providing important educational benefit to the next generation of designers learning to address the challenges they will face in their future careers (Cerra, 2016c; Marcell, 2016). Incorporating stakeholders into the student learning process allows students to gain practical experience while participating stakeholders are educated about climate change (Cerra, 2016). Participants can become ambassadors for building resilience; helping their communities expand capacity for envisioning ways to adapt and even thrive in a future with a changing climate (Zemaitis, 2017).

As the CAD program continues to grow and evolve, tracking and evaluating the ways it is impacting the resilience of participating communities will enable the continual improvement of the program. This thesis is a first step in that process, utilizing survey and case study analysis to develop initial recommendations for improving the program. Such evaluation should continue, and reevaluation of the resilience of participating communities at set times after CAD should be considered. Recommendations based on this initial review include increasing stakeholder engagement through expanded outreach, and providing greater financial and technical support for communities to implement ideas developed from CAD student designs, including linking to other Estuary Program inititatives.

Integrating CAD into the Hudson River Estuary Program has been part of a process allowing the organization to grow its traditional education and conservation roles to include climate change adaptation and planning. CAD has also been a way for the Estuary Program to expand stakeholder outreach, using the excitement of imagery and potential to imagine the future to interact with businesses and residents who may not have previously been involved with the municipality or the Estuary Program. In interviews, municipal liaisons from the three participant communities all felt that CAD was valuable and are glad to have been involved, further supporting the case for continuing or expanding the program (K1, 2016; H1, 2016; C1 2016; H2, 2017; Richards, 2017). CAD gives communities the chance to plan necessary climate adaptation and even begin that work, making themselves more resilient in the process.

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Appendices

Appendix A. Science and Policy Context

This appendix gives a brief overview of the scientific context that informs the discussions of mitigation, adaptation, and resilience in this thesis. First, I describe current climate change science and terminology. Next, I discuss resilience from an ecological perspective, which is the basis for the multidisciplinary approaches to resilience described in this thesis. Also provided here is a short review of global and national climate policy to better describe context of New York State and Hudson River Estuary Program initiatives.

Science Context

Climate Change

The earth's climate has gone through natural cycles and of cooling and warming throughout its existence, and those cycles continue. However, the current warming trend referred to in this thesis as climate change is distinct in the speed of warming and the primary cause, human activity (IPCC, 2014). This warming is caused by the release of greenhouse gases (GHG) such as carbon dioxide and methane by multiple agricultural, industrial, and transportation processes (IPCC, 2014). The Intergovernmental Panel on Climate Change, the international body tasked with observing climate change, predicting future change, and developing recommendations for action based on those observations and predictions, states in its most recent "Climate Change Synthesis Report"

> *"Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems…Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia." (IPCC 2014, p.2)*

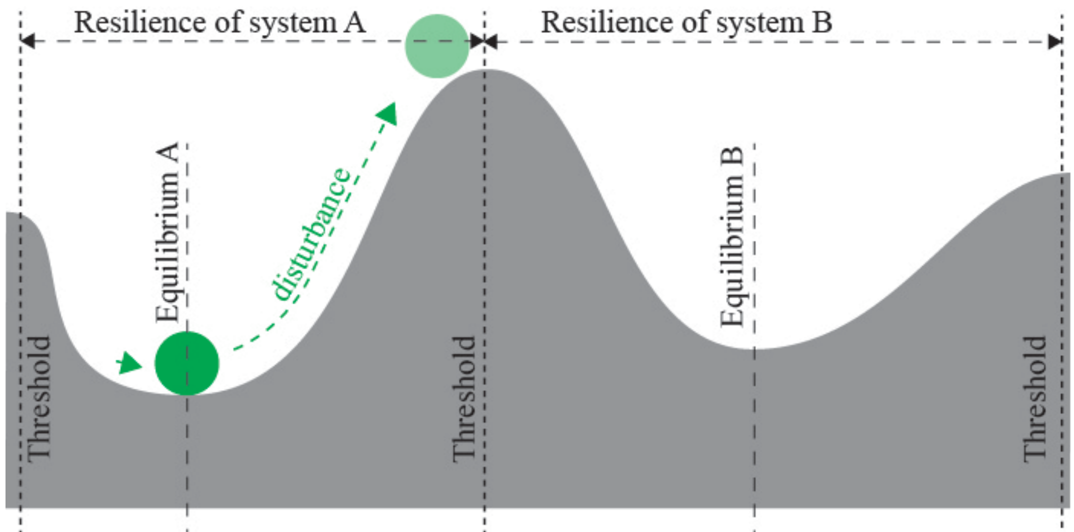
As our climate warms, the occurrence of natural events that may be detrimental to our current ecosystemic regime increases (IPCC 2014). *Climate change hazards* refer to these natural events such as storms or droughts that are not necessarily caused by climate change but amplified or altered by it (Doria et al., 2009; IPCC, 2014). *Climate change vulnerability* is generally a question of magnitude and can be thought of as estimating how much damage a hazard would cause if it occurred (IPCC, 2014). This estimated damage is determined by the magnitude of the hazard as well as the state of the system impacted by it (Doria et al., 2009; IPCC, 2014). Similarly, *climate change risks* are defined by the Intergovernmental Panel on Climate Change as the result of

> *"the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems, including their ability to adapt" (IPCC, 2014 p.13).*

While hazards are simply events, vulnerability is the amount of damage those events could cause, and risks are the chance of those events occurring (Doria et al., 2009; IPCC, 2014).

Ecological Resilience
While the general focus of this work is on humans and social systems, human actions significantly impact natural systems through multiple methods and often by attempting to change, preserve, or restore specific ecosystems to suit our needs (Bellard et al., 2012; Lovell & Johnston, 2009). Equally true is that humans interact with and are impacted by the larger ecosystem in a multitude of ways, most notably by providing 'ecosystem services' (Eakin & Luers, 2006; Lovell & Johnston, 2009). Lovell and Johnston (2009) describe these services as broken into categories including production of raw goods and resources, cultural and recreational space, and regulation or buffering capacity to absorb or mitigate potentially harmful events.

Ecological systems tend toward states of equilibrium or balance, and are subject to disturbance by forces both natural and human-caused (Eakin & Luers, 2006; Gunderson, 2000). Resilience in these systems is defined as "the magnitude of disturbance that can be absorbed before the system redefines its structure…" (Gunderson, 2000 p. 426). If the system is subject to a relatively minor disturbance such as a storm, its resilience can allow it to return quickly to an equilibrium state (Gunderson, 2000). However, a larger disturbance such as early spring thaws repeating over several years, will cross a 'threshold' of the system's resilient capacity, leading it to shift to a new structure, resilient capacity, and equilibrium (Gunderson, 2000). See the figure below for a diagram of this process. [6]



Ecological equilibrium, threshold, and resilience
Source: Gunderson, 2000.

[6] For a review of the potential impacts of climate change to biodiversity and global ecology, "Impacts of climate change on the future of biodiversity" by Bellard, et al. (2012) is a good introduction.

Policy Context

Global Climate Policy

Though attempts to respond to the global crisis of climate change began in the late 1980s, progress has been slow and uneven globally (Chasek et al., 2010). The major international body convening experts on climate change research and advising climate policy development is the Intergovernmental Panel on Climate Change (IPCC), formed in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to bring together scientists studying growing evidence that the climate was changing at an unprecedented rate due to human activity (Bodansky, 2011). To attempt to limit human's impact on the climate, the United Nations Framework Convention on Climate Change (UNFCCC) established in 1992 at the Rio Earth Summit created a forum in 1992 to negotiate greenhouse gas (GHG) emissions (Bodansky, 2011). Negotiations began in 1992 however an international agreement setting reduction goals and monitoring levels for GHG was not reached until 1997 and not ratified and enacted until 2005 (Bodansky, 2011; Chasek, et al., 2010). Notably absent from the signatories to the Kyoto protocol was the United States.

As the Kyoto Protocol reinforced Europe's work on GHG reduction, non-signatory nations that are major emitters of GHG such as the United States, China, and India, did not reduce emissions as substantively (Chasek, et al., 2010). International negotiations among the UNFCCC at multiple Conference of Parties (COP) over several years finally resulted in the world's largest emitters (including the United States) agreeing to somewhat tangible goals at COP 21 in Paris in 2015 (Obergassel et al., 2016). Though specific emissions targets were not developed, the parties did commit to limit global warming to 2º C, with each signatory tasked with reducing GHG emissions to achieve this goal and reporting on their progress (Obergassel et al., 2016). Based on the COP 21 agreement, China and India are developing emissions reduction plans to varying degrees of praise and criticism, and Europe is continuing its work (Obergassel et al., 2016).

Federal Climate Policy

Since the late 1908s, the United States' has swung from resisting to leading climate research and mitigation efforts, largely depending on the party in power (Bodansky, 2011). Republicans have resisted agreeing to any internationally sanctioned GHG reduction scheme citing potential economic harm, while Democrats have argued for the necessity of action to protect the nation and its interests (Bodansky, 2011). Reagan and Bush delayed action, citing the need for further study in a relatively new field (Chasek et al., 2010). Clinton actively negotiated the Kyoto protocol and pledged to sign it, but did not have the chance as W. Bush was elected before the document was finalized (Bodansky, 2011; Chasek, et al., 2010). W. Bush backed out of the agreement and repeated the Republican party line of needing further information before acting, adding on the sentiment that it was unfair for the United States to reduce its emissions while major emitters such as China and India were not acting (Bodansky, 2011; Chasek, et al., 2010).

During the Obama administration, the United States did make an effort to undertake mitigation, implementing stricter vehicle emissions standards and working through the EPA on rules such as setting Clean Air Act levels for carbon dioxide, and the 'Clean Power Plan' to reduce power plant emissions (Burtraw, 2015). However, the legislative branch made any progress difficult and successfully prevented implementation of the Clean Air Act rules as well as the Clean Power Plan (Doinger, 2017). It remains to be seen how the Trump administration will handle the United States' commitments from Paris (Halper, 2017). During the campaign, Trump pledged to back out of the 'Paris deal' but this plan faces some uncertainty as the Republican party does not have a coherent stance on the agreement (Halper, 2017).

Obama also issued guidance for federal agencies to begin considering climate change in all policies and projects; this guidance has notably been taken to heart by the department of Housing and Urban Development (HUD) (Adams-Schoen & Thomas, 2015). HUD is responsible for large investments in cities throughout the country, has established a Resilience Council, and wrote a specific Climate Change Adaptation Plan for its ongoing work (Adams-Schoen & Thomas, 2015). Though these actions were important steps, since they were predominantly through executive rule making, it remains to be seen how many of them survive the Trump presidency.

Federal Flood Policy

Flood policies from the Obama administration also promoted climate adaptation (Adams-Schoen & Thomas, 2015). One example is the creation of the Federal Flood Risk Management Standard (FFRMS) which calls on the Federal Emergency Management Agency (FEMA) to examine flood plain maps and standards, potentially revising them to account for sea-level rise (Adams-Schoen & Thomas, 2015). Another important step is guidance issued by FEMA requiring the inclusion of expected climate change impacts in mandatory state hazard mitigation planning (Adams-Schoen & Thomas, 2015).

The updated flood maps required by the FFRMS are to be used in drawing floodplain and FEMA flood insurance boundaries (Adams-Schoen & Thomas, 2015). Flood insurance is required for mortgages on all properties within the FEMA-defined floodplain (Atreya & Kunreuther, 2016). By requiring flood insurance for mortgages and then setting standards for construction and rates, FEMA effectively regulates construction within the floodplain (Atreya & Kunreuther, 2016). To promote greater resilience and disaster planning among communities within floodplains, FEMA has developed the "Community Rating System" (FEMA CRS) (Atreya & Kunreuther, 2016).

The incentive mechanism for municipal participation in the CRS is a discount on federal flood insurance premiums for property owners within that community (FEMA, 2016). In order to qualify for these discounts, communities document their qualifying actions to gain points, with a higher score resulting in greater discounts (Atreya & Kunreuther, 2016).

Atreya and Kunreuther (2016) describe the city of Ottawa, Illinois undertaking a resilience-enhancing CRS action, educating residents. The city educated its residents about their past and future flood risk, resulting in voters approving a significant expenditure to relocate a school out of a flood-prone area (Atreya & Kunreuther, 2016). As a national program with the potential to significantly impact CAD communities, it is essential to consider the CRS and wether CAD designs can contribute to a community's qualification for the program.

Appendix B. Resilience Metric

Community Resilience Metric - Questionnaire

	<u>**Elements contributing to resilience**</u>	**Question**	**1 (minimal)**	**2**	**3 (moderate)**	**4**	**5 (high)**
Community							
Leadership	Effectiveness of elected leaders	**1A**					
	Environmental issues a priority	**1B**					
	Honestly assesses risks	**1C**					
	Ability to leverage outside support	**1D**					
Good governance	Transparency/ communication	**1E**					
	Responsive to community concerns	**1F**					
	Concern/ consideration for disadvantaged groups	**2I**					
Stakeholder engagement	Willing to devote time/ effort to projects	**2A**					
Education	Educated about plans	**1C**					
	Educated about climate change + risks	**2G**					
Social capital	Mutual aid (assist each other in times of need)	**2H**					
	Businesses/ Nonprofits are active	**2B**					
	Pride in community/ feeling of 'belonging'	**2F**					
Physical Environment							
Infrastructure	Condition of infrastructure	**2C**					
Environmental hazards	Plans are being made to address environmental hazards (ie brownfields)	**2D**					
Outlook							
Long term planning	Climate change is being considered in planning/ decision making	**1C**					

Appendix C. Resilience Questionnaire

Thank you for taking 5 - 10 minutes of your time to improve our understanding of community resilience in the Hudson Valley.

About this survey:
My name is Gabrielle Weiss and I am a graduate student in Environmental Policy at Bard College and an intern with NY DEC Hudson River Estuary Program. I am conducting research on community resilience for my Master's thesis. The purpose of this survey is to learn about your perspective on how your community is dealing with challenges related to climate change.

You will be asked to rate your agreement with statements and be given an opportunity to write in comments within each section of the survey. If you do not feel comfortable answering a question, you may leave it unanswered.

Because your responses will be confidential, the only risk associated with completing this survey is possible fatigue from answering the questions. The main benefit of participating in this study is furthering research on climate resilience and improving ongoing work by the Estuary Program to assist communities in adapting to climate risks. With your consent provided by your signature below, I may quote and/or paraphrase any written responses you provide in my thesis. My Master's thesis will be publicly available at the Stevenson Library on the Bard College Campus and given to the Hudson River Estuary program to help them better understand resilience in the Hudson Valley.

Participant's Agreement:
I am aware that my participation in this survey is voluntary. I understand the intent and purpose of this research. If, for any reason, at any time, I wish to stop the survey, I may do so without having to give an explanation.

The researcher has reviewed the individual and social benefits and risks of this project with me. I am aware that my responses will be used in a thesis that will be a public document once completed and that it will also be publicly available at the Stevenson Library on the Bard College Campus.

If I have any questions about this study, I am free to contact the student researcher, Gabrielle Weiss at gw3796@bard.edu or 617-888-9869, or the faculty adviser, Dr. Monique Segarra at segarra@bard.edu or 845-758-7869. If I have any questions about my rights as a research participant, I am free to contact the Bard Institutional Review Board at irb@bard.edu.

By signing below, I certify that I have been offered a copy of this consent form, and that I have had the opportunity to ask questions. If applicable, all questions I have asked have been adequately answered.

By signing below, I consent to the use of my survey responses:

____ _______________
Participant's signature Date

These questions will allow me to understand how you have been involved in work in [municipality]. While you do not need to identify your profession, I would like to know about your work in general. Your responses will be confidential.

A. Do you live in the [municipality] of [municipality name]? Yes No

B. Do you work for the [municipality] of [municipality name] or any other public agency? Yes No

C. Do you work for a non-profit or other organization that partners with the [municipality]? Yes No

Remember that these responses are confidential and are being used to help improve the Estuary Program's collaboration with communities.

These statements are about leaders and officials in the [municipality type] of [municipality name]. Please focus on how you feel about [municipality type] staff and public officeholders, and how the [municipality type] is governed. Please do not consider any other local governments in your responses.

Circle the number that corresponds to your opinion:
1) strongly disagree 2) disagree 3) neutral 4) agree 5) strongly agree

A. I have respect for the [leader type] and feel they can impact [municipality] in a positive way. 1 2 3 4 5

B. I think environmental issues are a priority for [municipality]. 1 2 3 4 5

C. I think that Kingston's government understands climate change risks and is planning for them. 1 2 3 4 5

D. I think [municipality] has the ability to face future challenges related to climate change or knows how to get help with those challenges. 1 2 3 4 5

E. [municipality] officials clearly communicate guidelines, plans, and projects to the community. 1 2 3 4 5

F. I think [municipality] government is open to concerns and ideas from residents. 1 2 3 4 5

G. Do you have any comments, ideas, or opinions about the leaders in your community that you would like to share?

____

____

____

____

____

Do you give permission to quote this response? Yes No
(any names or identification in your response will be removed)

These statements are about your feelings about [municipality type] of [municipality name]. Please focus on [municipality name]'s environment and how you feel about being a member of the community.

Circle the number that corresponds to your opinion:
1) strongly disagree 2) disagree 3) neutral 4) agree 5) strongly agree

A. I believe residents are engaged in the community and willing to devote time to community projects.	1	2	3	4	5
B. I have seen business owners, religious groups, and other community groups active in our community.	1	2	3	4	5
C. In my experience, roads, water lines, and other public facilities are well-taken care of in [municipality].	1	2	3	4	5
D. I know of plans in [municipality] to deal with possible environmental hazards (such as old industrial land, pollution).	1	2	3	4	5
E. I know of plans in [municipality] to deal with climate change.	1	2	3	4	5
F. I am proud to be a resident of [municipality].	1	2	3	4	5
G. I think my neighbors know about climate change and its risks.	1	2	3	4	5
H. In my experience, during a disaster [municipality] residents work together to support and assist each other.	1	2	3	4	5
I. I feel that [municipality] government and residents are concerned about the well-being of disadvantaged groups.	1	2	3	4	5

J. Do you have any comments, ideas, or opinions about the [municipality] would like to share?

____

____

____

____

Do you give permission to quote this response? Yes No
(any names or identification in your response will be removed)

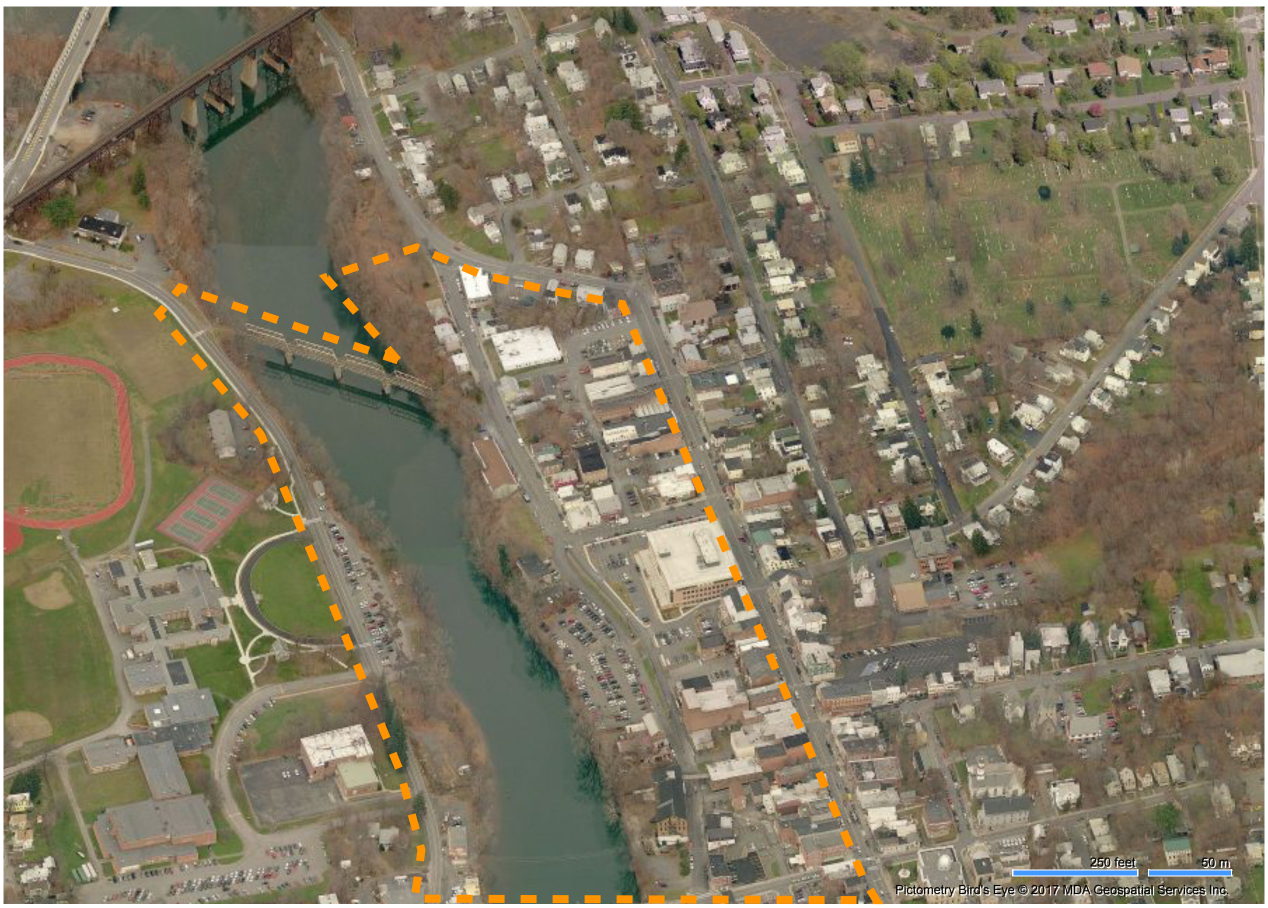
Appendix D. Successful Adaptation Tracking

This tool is designed to be completed for a single municipality.

Kingston, NY Fall 2016			
Adaptive Action	**Element(s) of resilience addressed**	**Type of project (plan v. activity)**	**State of completion**
Abbreviations: L Leadership, GG good governance, SE stakeholder engagement, E education, SC social capital, IC infrastructure & construction, EH environmental hazard management, P planning			

Appendix E. Site Aerial Photos

Aerial photographs of each site are shown below, with the approximate site boundary outlined by a dashed orange line.



Catskill, NY CAD project site
Source: Bing imagery

Hudson, NY CAD project site
Source: Bing imagery

Kingston, NY CAD project site
Source: Bing imagery